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HANDBOOK
FOR
GAS WELDERS

SP : 12 - 1975
(Reaffirmed 2003)

HANDBOOK
FOR
GAS WELDERS

(Fourth Reprint MARCH 2004)

UDC 621 791 5 658 386 621 791(026)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002

Gr 15 *May* 1976

Edition 1 - 1976
(Fourth Reprint MARCH 2004)
UDC 621 791 5 658 386 621 791 (026)

SP : 12 - 1975

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Printed in India by Printograph, New Delhi and
Published by Bureau of Indian Standards, New Delhi 110002

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FOREWORD

At the instance of Planning Commission, Government of India, Indian Standards Institution (ISI) launched a Steel Economy Project in the early 1950s. The object of this programme was to prepare a series of Indian Standard specifications and codes of practices in the field of production and use of steel.

One of the subjects under the Steel Economy Project is that pertaining to popularization of welding as a mode of fabrication. As a result of intensive study made during the last two decades and deliberations at numerous sittings of Technical Committees, a number of Indian Standards have been published in the field of welding. A complete list of Indian Standards on welding is given in Appendix B

Production of sound and economic welds depends to a large extent on the welder himself. Thus, a trained welder with a fair amount of theoretical knowledge would be able to carry out welding jobs efficiently and economically. It was, therefore, felt necessary that in addition to the publication of codes of practices and design standards the welders should be systematically trained in this country and handbooks giving theoretical and practical information in simple language should also be made available to them for their reference purposes.

With this object in view, Indian Standard codes of practices for training of manual metal arc welders (IS : 817-1966) and gas welders (IS : 1393-1961) have been published. This handbook is the second in the series of handbooks on welding, and deals with gas welding. The first handbook relates to manual metal-arc welding. A handbook for welding engineers is under prepartion.

This handbook requires reference to the *Carbide of Calcium Rules, 1937* with its subsequent amendments issued by the Government of India.

In the preparation of various sections of this Handbook, the Sectional Committee has derived valuable assistance from authors as mentioned below for the sections shown against them:

Section	*Author*
1. Introduction	Shri R. Ghosh
2. Production and Distribution of Gases	Shri R. Ghosh
3. Oxy-acetylene Equipment and Accessories	Shri R. Purkayastha
4. Safety in Welding	Shri S. S Mazumdar
5. Welding Metallurgy	Shri V. R. Subramanian
6. Filler Rods and Fluxes	Shri R. Purkayastha

Section	*Author*
7. Welding Technique and Procedure	Shri R. Purkayastha
8. Oxygen Cutting	Shri J. C. Acharya
9. Inspection and Testing	Shri V. R. Subramanian
10. Estimating and Costing	Shri J. C. Acharya

This assistance was made available to ISI through the courtesy of M/s Indian Oxygen Limited, Calcutta.

This handbook, which has been processed by the Welding General Sectional Committee, SMDC 14, the composition of which is given in Appendix C, had been approved for publication by the Structural and Metals Division Council of ISI.

No handbook of this type can be made complete for all times to come at the very first attempt. During the course of use of this handbook it should be possible to make suggestions with regard to improving its utility. All such suggestions may be passed on to ISI who will receive them with appreciation and gratitude. These suggestions will be taken into consideration while revising the handbook.

SECTION I

INTRODUCTION

1.1 General

This handbook deals with gas welding and allied processes done by hand — the term allied processes in addition to gas welding means braze welding, brazing, oxygen cutting and such similar processes needing the application of a flame using a fuel gas and oxygen or air. This handbook deals in simple language with the various aspects of these processes which will be of practical utility to the welder. Some of the common welding terms which a welder is likely to come across are explained in Appendix A. For complete list of welding terms reference should be made to IS : 812-1957 'Glossary of terms relating to welding and cutting of metals'. The important aspects covered in this handbook are welding gases, welding and cutting equipment, welding techniques and procedure, welding filler rods and fluxes and safety in welding. Elements of welding metallurgy have also been explained to assist the welder to adopt suitable welding procedures. Method of inspection and testing of welds, and of estimating and costing of welds have also been included as knowledge of these will assist welders in producing economical and quality welds.

1.2 Definition

Welding is a method of joining metal. The faces to be joined are heated locally, in case of gas welding with a gas flame, until the faces become sufficiently hot or plastic or liquid and the joint is effected either by the application of pressure or by the application of a filler rod or wire. The process where the pressure is applied, is popularly known as 'forge welding' or 'pressure welding'. When the faces to be joined are heated and rendered liquid, application of pressure not being necessary, the process is known as 'fusion welding'; in this process some times additional metal is added to the joint by melting a metallic rod called filler rod or wire or metal.

1.3 Historical Development

The art of joining metal is about 3 000 years old. In India, probably the oldest surviving piece of welding is in the Iron Pillar at Delhi which is about 1 500 years old. It was discovered a long time ago that by heating two peices of metal and then by hammering the heated ends together, the two pieces could be joined in one continuous piece. The Iron Pillar was probably made by this method. This discovery was the fore-runner of what is now known as the forge welding or blacksmith welding — a process which finds application from a village smithy to a large modern forge shop.

The next discovery was the flame obtained by burning acetylene gas in air or oxygen; acetylene when burnt with air produces a flame having temperature of about 2 325°C and when burnt with oxygen a flame temperature of about 3 200°C is reached Where acetylene is used with oxygen for gas welding it is known as oxy-acetylene welding The edges of the metal pieces to be joined are placed adjacent to each other and melted together so as to form one piece after cooling, filler metal may be added by using filler rod to give the required size and shape to the final joint Fuel gases other than acetylene, namely, propane, butane, hydrogen, coke oven gas and coal gas have been used in conjunction with oxygen (and in some cases with air) to produce a flame as heat source for application of processes allied to gas welding such as oxygen cutting, brazing, etc In this country acetylene is the more popular fuel gas for gas welding and allied processes

A French chemist A L Lavoisier in his experiments (1770-1775) first recognized oxygen as an element although this was first produced in 1772 by K W Scheele The industrial use of oxygen had to wait many years till oxygen was produced in some commercial quantities by the Brin Process by heating barium monoxide to peroxide in compressed air and then raising the temperature and reducing the pressure to bring about the reversion of barium dioxide to the monoxide and oxygen The Brin process is now an obsolete process The chief commercial source of oxygen today is atmosphere which contains about 21 percent oxygen in addition to nitrogen, argon, carbon dioxide and other rare gases Oxygen is obtained by liquefaction of air and fractional distillation of liquid air The pioneers of this process of oxygen production were Claude and Linde towards the end of last century

Acetylene was discovered and identified in 1836 by Edmond Devey It was not, however, till 1892, until the discovery of production of calcium carbide in electric arc furnace by Willson and Morehead, the production and usage of acetylene became a commercial reality Whilst the use of acetylene for illumination purposes preceded the use of acetylene in conjunction with oxygen producing the hottest flame then known, the use of oxy-acetylene flame for fusion welding and allied processes surpassed most other uses of acetylene

In the year 1885, a Russian scientist M V Bernados discovered the process of electric arc welding employing a carbon electrode In 1890 Slavinoff improved the process developed by Bernados by replacing the carbon electrode with a metallic electrode Coated metallic electrode was first introduced by Oscar Kjellberg of Sweden in 1907 and for the first time it enabled metal arc welding to be accomplished with a stable arc and at the same time protected the metal transfer and molten weld deposit from atmospheric contamination This method of welding is known today as shielded arc welding

Many new developments have since taken place in the field of welding and today most of the ferrous and non-ferrous metals and even some of the non-metals, such as thermoplastics, may be welded by different welding processes. The chart showing derivation of the major welding methods that are commonly in use is given in Fig 1 1

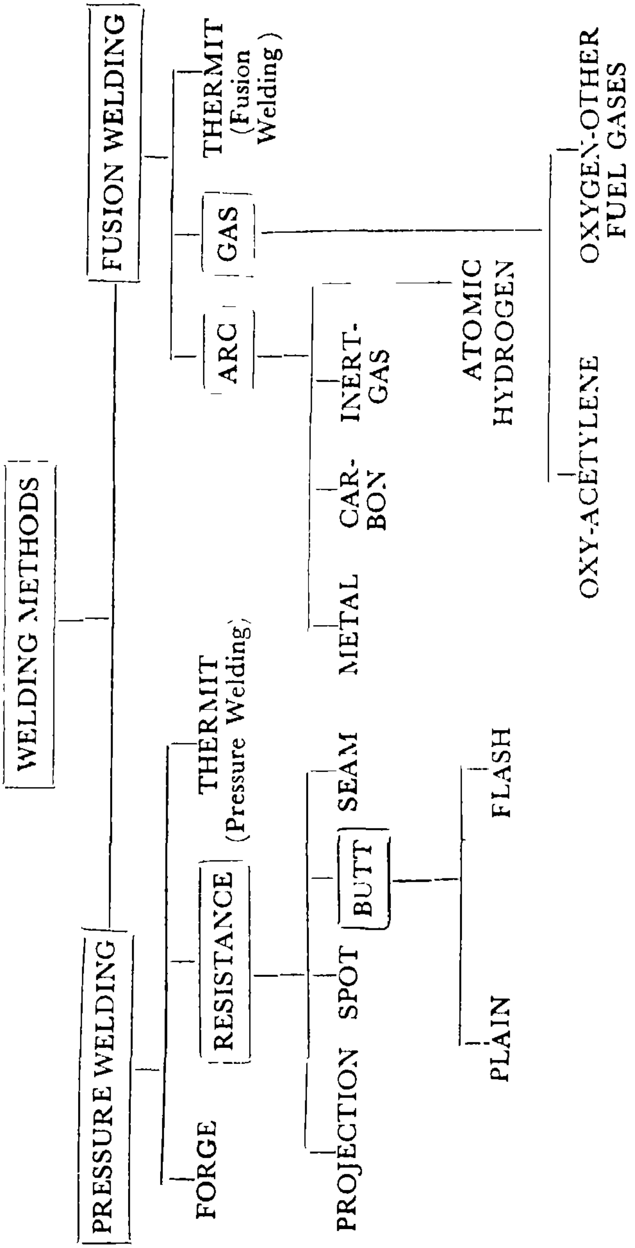


FIG. 1.1 CHART SHOWING WELDING METHODS

1.4 General Principles

Practically all gas welding today is done by the oxy-acetylene flame, although for brazing and some flame heating applications fuel gases other than acetylene are used. In this country, liquefied petroleum gas (LPG) is used for oxygen cutting in some areas where it is available in commercial quantities. LPG available in India contains a high percentage of butane consequently the thickness of steel that can be cut using LPG as a fuel gas is somewhat restricted. Coke-oven gas is also used as a fuel gas for oxygen cutting.

In gas welding oxy-acetylene flame is mainly used and the temperature of this flame is about 3 200°C. This tremendous heat of the flame is concentrated at about 1·5 mm away from the end of the inner cone of a neutral oxy-acetylene flame When this flame is applied to the surface or edge of a metal piece, the surface temperature of the part under the flame is raised and the flame ultimately melts a small pool of metal in the work. In case of fusion welding the filler rod is also melted by the heat of the oxy-acetylene flame and deposited in a molten state In most cases the molten metal in the pool is agitated by the action of the flame and by the filler rod, thus the base metal and the weld deposit are thoroughly mixed with the result that after cooling a sound union is formed.

Steel in its molten state tends to combine with oxygen and nitrogen of the atmosphere and forms compounds called oxides and nitrides. These compounds weaken it and make it brittle. In oxy-acetylene welding, the envelope or the outer-flame zone contains carbon monoxide and hydrogen. These are reducing gases and protect the molten steel from atmosphere and prevent formation of nitrides and oxides.

Notwithstanding the protective atmoshpere of carbon monoxide and hydrogen in the outer zone of the oxy-acetylene flame, it becomes necessary to use fluxes when welding some metals and alloys for other metallurgical reasons for obtaining sound weld deposits. In the case of braze welding or brazing, it is not necessary to raise the parent metal mating faces to its melting point.

The various sections in this handbook deal in detail the important aspects of gas welding, so that welders can appreciate the important technological aspects of gas welding process and make sound welds at the most economical cost.

SECTION 2

PRODUCTION AND DISTRIBUTION OF GASES

2.1 General

To produce the heating flame required for gas welding, oxygen metal cutting, brazing and allied processes, a combustible or a fuel gas must be burnt in conjunction with oxygen or air, which is essential to support the combustion.

2.2 Manufacture of Gases

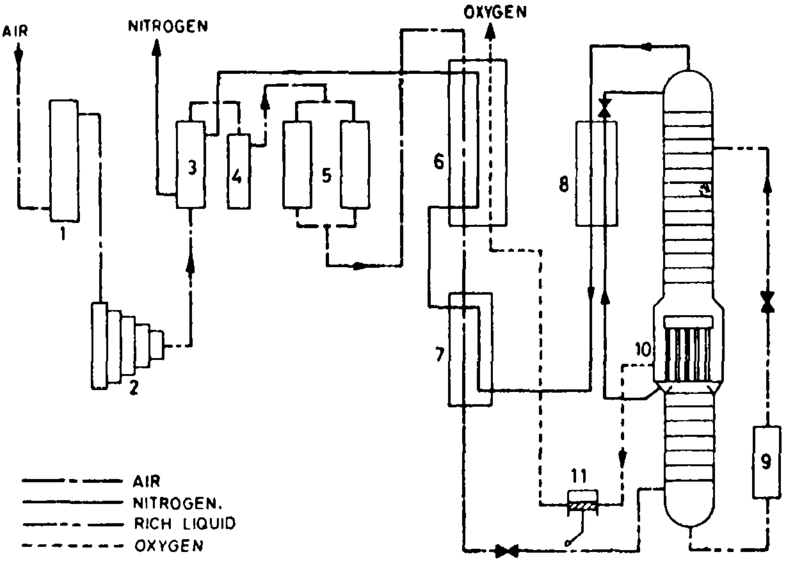
2.2.1 *Oxygen* — Most of the oxygen which is industrially used is obtained by extraction from atmosphere which contains approximately 21 percent oxygen by the liquid-air process. Some amount of oxygen is obtained as a by-product in the electrolysis of water — a process which also produces hydrogen along with oxygen. Hydrogen obtained by this process is mainly used for hydrogenation of oil and fat and oxygen produced is sometimes compressed into cylinders for industrial applications. However, the volume of oxygen obtained by this process is small and is not the economical method of oxygen production.

In the liquid-air process, air is liquefied enabling the oxygen to be separated from the nitrogen by fractional distillation method In the process illustrated in Fig. 2.1 gaseous oxygen is produced.

The process air is drawn in by the multistage air compressor through the low pressure (LP) caustic scrubber, where the carbon dioxide in the air is removed. The high pressure air (HP) then passes through the vaporization cooler and then through the water separator where the free moisture is removed. The high pressure air then passes through the drying battery where the air is rendered dry. The air then passes through the precooler where it is cooled down by the product liquid oxygen and return waste nitrogen. The HP air is further cooled down in the main heat exchanger by the waste nitrogen The air expanded in a throttle valve enters the bottom of the double rectification column. The rich liquid from the bottom of the lower column enters the acetylene absorber and then enters the upper column after it is expanded in a throttle valve. The product liquid oxygen from the bottom of upper column is sucked in by the pump and is delivered through the precooler where liquid oxygen evaporates. The gaseous oxygen is then filled in cylinders at a pressure of 120 kgf/cm^2.

In the other liquid air process illustrated in Fig. 2.2 both gaseous and liquid oxygen are produced.

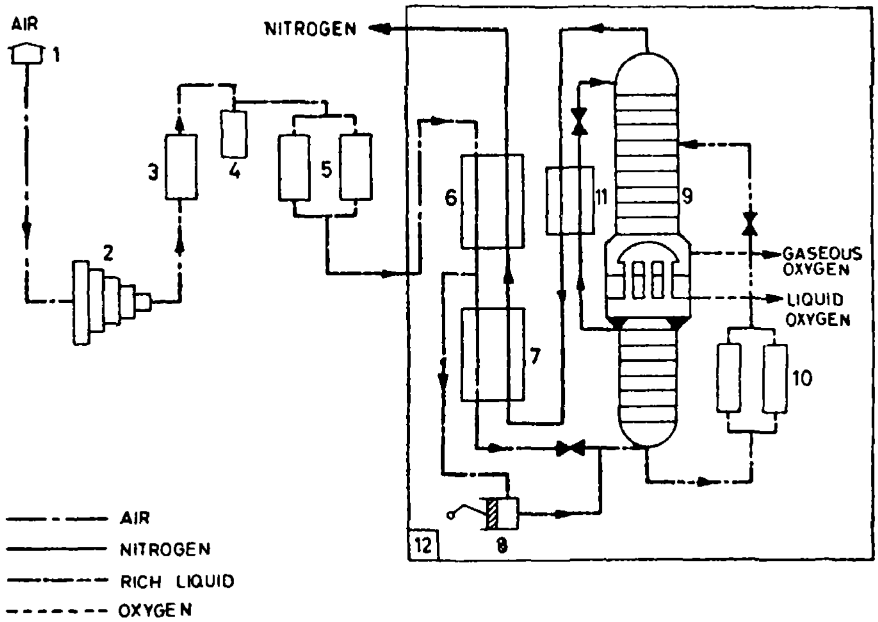
The process air is drawn in by the multiple stage air compressor hrough the air filter where any suspended dust particle in the air is



1. Caustic scrubber
2. Air compressor
3. Vaporization cooler
4. Water separator
5. Alumina drier
6. Precooler
7. Main exchanger
8. Poor liquid/waste nitrogen cooler
9. Acetylene absorber
10. Rectification column
11. Pump

Fig. 2.1 Liquid-Air Process of Producing Oxygen

removed. The high pressure air after the final stage of the compressor is passed through freon cooler and then through water separator where free moisture in the air is separated. The high pressure air is then passed through the absorber battery where the air is made dry and the carbon dioxide present in the air is removed. The pure dry air enters the cold box and is cooled in the precooler by the return waste nitrogen. A portion of the precooled compressed air goes to the expansion engine which supplies relevant refrigeration for maintaining the plant at the required low temperature. The remaining portion of the high pressure air passes through the main exchanger where it is further cooled by the return waste nitrogen. The high pressure air is then expanded through a throttle valve and enters the bottom of the double rectification column along with expanded air from expansion engine. The rich liquid from the bottom of the lower column enters the acetylene absorber where any hydrocarbon present is removed. It is then expanded to the upper column pressure. The product liquid oxygen from bottom of the upper



1. Air filter
2. Air compressor
3. Freon cooler
4. Water separator
5. Carbon dioxide absorber
6. Precooler
7. Main exchanger
8. Expansion engine
9. Double rectification column
10. Acetylene absorber
11. Poor liquid/waste nitrogen cooler
12. Cold box

FIG. 2.2 LIQUID-AIR PROCESS OF PRODUCING OXYGEN, AN ALTERNATIVE TO FIG. 2.1

column is taken out to the liquid storage vessel continuously along with gaseous oxygen from the top of the condenser. The gaseous oxygen is stored at a pressure of 120 kgf/cm^2. For large scale oxygen requirements often the supply is made as liquid oxygen which is stored at site in specially insulated storage vessel and evaporated and distributed through a pipeline in the workshop for use.

2.2.2 *Fuel/Combustible Gases*

There are several fuel or combustible gases which are commercially available, these vary in usefulness of application, mainly according to their heating capacity. The major fuel gases are as follows:

a) Acetylene,

b) Hydrogen,

c) Liquefied petroleum gases (LPG) — propane and butane,

d) Coal gas, and

e) Oven gas

2.2.2.1 *Acetylene* — Industrial acetylene is produced by the reaction of water on calcium carbide, which is a compound of calcium and carbon manufactured by the fusion of limestone and coke in an electric furnace (*see* Fig. 2.3). Acetylene for gas welding, oxygen cutting, brazing and allied processes can be produced at site in a small or a medium size generator or it can be produced on a large scale, purified and charged into cylinders filled *with porous mass and acetone (see Fig. 2.4). Acetylene filled in a cylinder* is usually known as 'dissolved acetylene'.

The production of acetylene for charging into cylinders is shown in Fig. 2.5 (*see also* Fig. 3.1). Calcium carbide is charged in the hopper of the generator and is fed into the generator tank at a predetermined rate by a helical conveyor. The generator tank is kept full of water and the water level is automatically controlled by a overhead flushing tank which also discharges the spent calcium hydroxide from the bottom of the generator tank. The acetylene gas then passes through the hydraulic main and stored in the gas holder. The acetylene compressor draws in gas through the purifier and the LP drier. The purifier is packed with purifying substance for the chemical removal of impurities. After the gas is compressed in the compressor it passes through the HP cooler and the HP drier unit for removal of moisture. The gas is then charged in the cylinders at the charging rack up to a pressure of 21 atmospheres where chilled water is sprayed on the cylinders to shorten the charging time. The balance gas holder is provided to stop the compressor motor when sufficient acetylene is not passing through the system. The chilled water needed for LP drier, HP cooler and charging rack is delivered by the pump from the refrigeration plant. The flashback arrestor will prevent any fire which may happen accidentally from proceeding towards the plant.

For site generation of acetylene, small type of acetylene generators are used which may be either carbide-to-water or water-to-carbide type (*see* Fig. 2.6).

2.2.2.2 *Hydrogen* — There are two main sources of availability of hydrogen (a) obtained by electrolysis of water, and (b) by-product from oil refineries — in the latter case, the gas is required to be purified to eliminate the unwanted gases. Hydrogen is filled into cylinders at a pressure of approximately 120 kgf/cm². Unlike acetylene cylinders, hydrogen cylinders are not filled in with any porous mass.

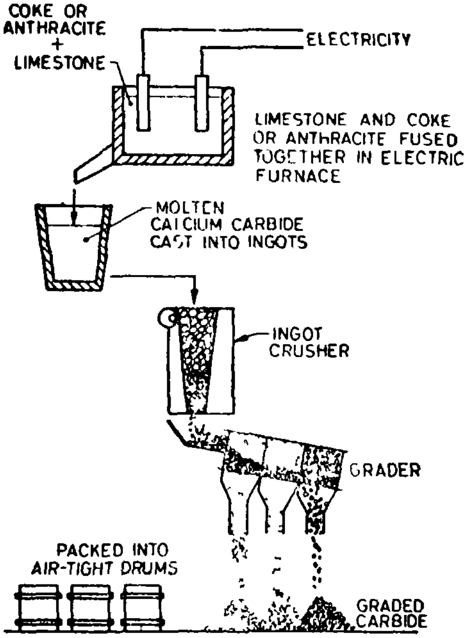

COKE OR
ANTHRACITE
+
LIMESTONE
ELECTRICITY
LIMESTONE AND COKE OR ANTHRACITE FUSED TOGETHER IN ELECTRIC FURNACE
MOLTEN CALCIUM CARBIDE CAST INTO INGOTS
INGOT CRUSHER
GRADER
PACKED INTO AIR-TIGHT DRUMS
GRADED CARBIDE

Fig. 2.3 Manufacture of Calcium Carbide

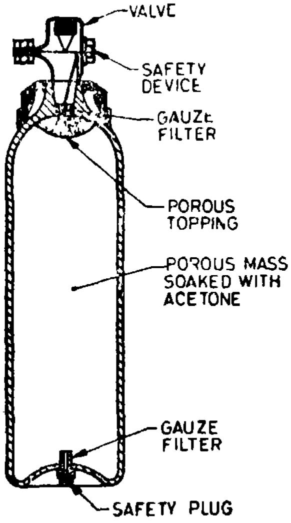
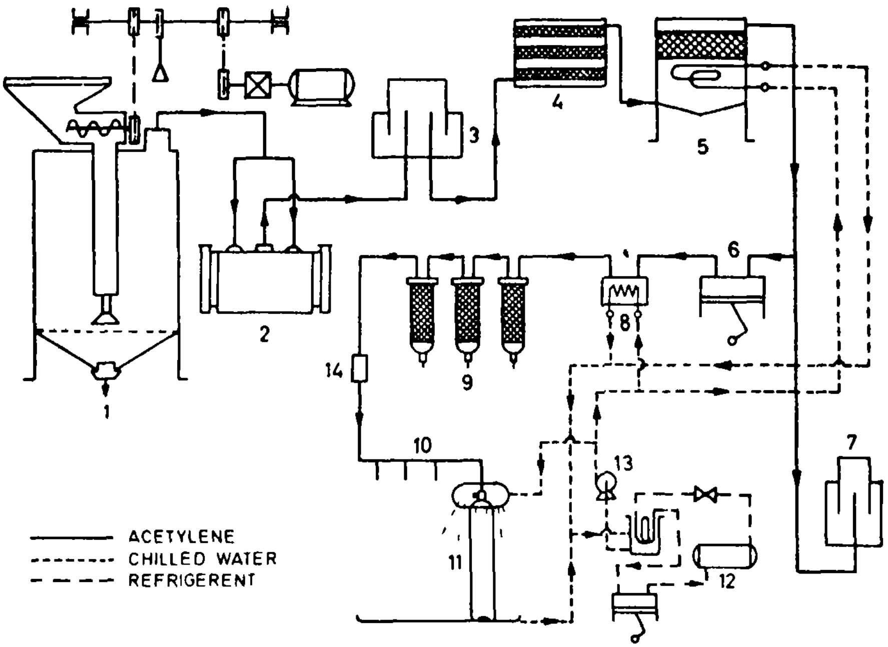


Fig. 2.4 Typical Dissolved-Acetylene Cylinder

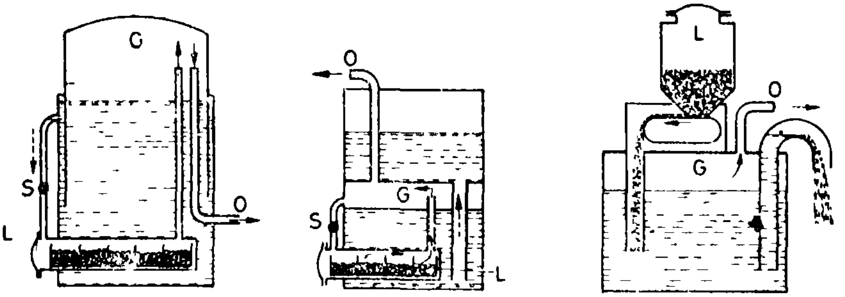


1 Acetylene generator
2 Hydraulic main
3 Gas holder
4 Purifier
5 LP drier
6 Acetylene compressor
7 Balance gas holder
8 HP cooler
9 HP drier
10 Charging rack
11 Dissolved acetylene cylinder
12 Refrigeration plant
13 Chilled water circulating pump
14 Flashback arrestor

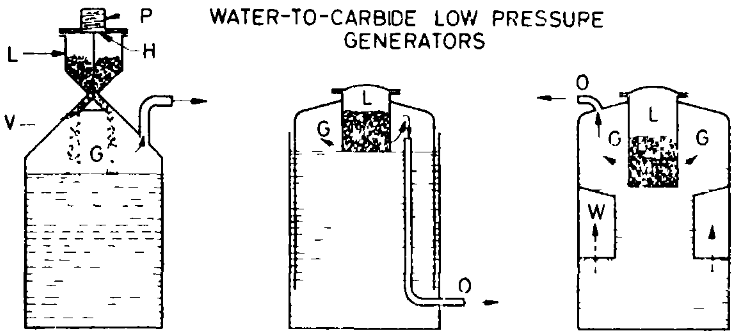
Fig 2 5 Production of Acetylene

2.2.2 3 *Liquefied petroleum gases* (*propane and butane*) — LPG is again a fuel gas obtained as a by-product from refining of petroleum Refined gas is compressed into cylinders in the form of liquid but when the valve is opened the liquid gas evaporates giving out fuel gas

2.2.2.4 *Coal Gas* — Coal gas is obtained from coal gas producing ovens Normally, coal gas is not compressed into cylinders as it deteriorates when compressed and stored for long period This gas is usually supplied to the consuming points by pipelines



WATER-TO-CARBIDE LOW PRESSURE GENERATORS



CARBIDE-TO-WATER LOW PRESSURE GENERATORS

G — Gas storage space

L — Carbide container

H — Diaphragm

P — Pressure control springs

S — Water pipe to carbide chamber, incorporating feed control device operated by gas volume

W — Water balance compartment

O — Gas outlet, usually fitted with a stop valve · gas passes to a purifier (if fitted) and a back-pressure valve to the blowpipe or pipeline

V — Carbide feed valve

FIG. 2.6 PRINCIPLES OF OPERATION OF THE MAIN TYPES OF ACETYLENE GENERATORS

2.2.2.5 *Oven gas* — Oven gas similar to the coal gas is produced from coke ovens. This gas, like the coal gas, is supplied to the consuming points by pipelines.

2.3 Distribution of Gases

2.3.1 *Oxygen* — In workshops where the requirement of oxygen is somewhat small, the supply is usually drawn from a suitable size single cylinder fitted with a regulator for reducing the cylinder pressure to the operating pressure required for gas welding and allied processes (*see* Fig. 2.7A *and* 2.7D).

If, however, large volume of oxygen is required on a temporary basis, two or more cylinders are coupled. When the demand is still larger, more cylinders are coupled together in a stationary manifold (*see* Fig. 2.7E). These manifolds usually have two banks of cylinders, one bank is kept in reserve while the other one is in use. The use of such manifolds very substantially reduces the cost of handling of cylinders inside the workshop. These manifolds are fitted with master regulators which reduce the cylinder pressure to about 15 kgf/cm^2 for feeding into a distribution pipe to the various consuming points. The consuming points are fitted with outlet valves, stop valves and regulators for individual pressure control at site for gas welding or oxygen cutting (*see* Fig. 2.7E).

When larger volume of oxygen is required, particularly if the area of operation is fairly concentrated, oxygen is supplied as liquid oxygen which is stored at the operation site in suitable insulated vessels and made to evaporate at a controlled rate and pressure. For supplies to various consuming points through a pipeline, similar to the one in case of manifold supply system referred to earlier the consuming points again are provided with stop valves and outlet points to which pressure controlled regulators are fitted for use with various welding or cutting equipment.

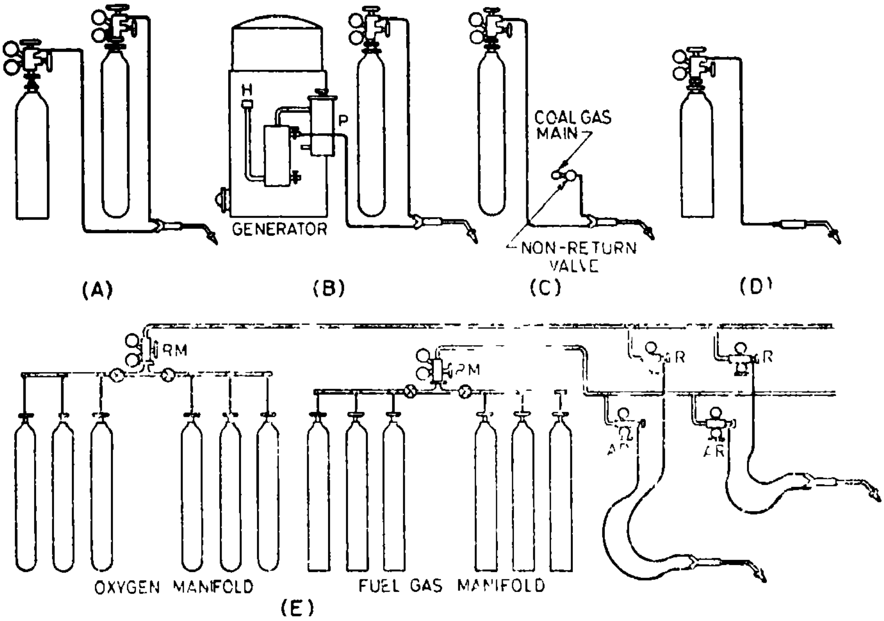
For supply of oxygen to very large consumption, oxygen produced in the factory is sometimes directly piped to the various consuming points. Such installations, however, exist in this country in larger steel works.

2.3.2 *Acetylene* When using acetylene from cylinders there are certain restrictions with regard to the rate at which cylinders can be emptied or the rate at which gas can be drawn from a filled acetylene cylinder. No cylinder should be emptied in less than 5 hours, that is, not more than 20 percent of the capacity of the cylinders should be drawn from the cylinder in an hour. There are, however, applications which may require supply of a volume of acetylene more than this permissible limit, in such cases acetylene cylinders must be coupled if the usage point is only temporary. For permanent requirements it would be desirable to have a manifold of cylinders (*see* Fig. 2.7E) as in the case of oxygen. Similar to the oxygen pipeline system, there exists acetylene pipeline system in which a number of acetylene cylinders are manifolded with one bank in use and the other bank in reserve. The cylinder pressure is, however, reduced at the manifold point to 0·6 kgf/cm^2 through a regulation system, the pipeline pressure being maintained at this pressure. Each outlet point of the manifold system has a flashback arrestor, stop valve and outlet point for fitting a suitable regulator.

For low pressure system, larger generators can be made to supply acetylene generator at site through a pipeline (*see* Fig. 2.7B). In such cases however, outlet point is fitted with a hydraulic back pressure valve.

2.3.3 *Liquefied Petroleum Gases* – Similar to acetylene supply system, the supply can be made from an individual cylinder or from cylinders coupled together or from a stationary manifold and pipeline.

2.3.4 *Coal Gas and Oven Gas* — Gas is drawn from pipelines at consumer points through a non-return valve (*see* Fig. 2.7C).



R — Oxygen regulator
AR — Acetylene regulator
RM — Manifold regulator

Fig. 2.7 Various Types of Welding and Cutting Installations

SECTION 3

OXY-ACETYLENE EQUIPMENT AND ACCESSORIES

3.1 General

Oxy-acetylene welding and cutting equipment are designed to provide the welder with means to control the welding flame accurately In choosing a welding outfit considerations should be given to the job requirements as well as the arrangements of gas supply with which the outfit is intend d to be used A designer of welding equipment takes all these factors into account besides such other basic requrements as safety in use and convenience in handling.

3.2 High Pressure and Low Pressure Equipment

An oxy-acetylene plant can be either: (a) a high pressure plant if it utilizes dissolved acetylene, that is, acetylene from cylinders, or (b) a low pressure plant if it utilizes an acetylene generator for producing acetylene In either case oxygen compressed into high pressure cylinders will be used.

NOTE — For large workshops piped oxygen and acetylene supplies are often used. Oxygen pipeline may be connected to manifold cylinder system or to a liquid oxygen supply system Acetylene pipeline may be connected to either a manifold dissolved acetylene cylinder system or to an acetylene generator

It will be seen that the terms ' high ' or ' low ' pressure equipment are based solely on the manner in which the acetylene is provided When acetylene from a dissolved acetylene cylinder is used the term 'high pressure' is applicable When acetylene is used directly from a generator it is called a ' low pressure ' system.

3.3 Acetylene Supply

3.3.1 *Dissolved Acetylene* — Dissolved acetylene or D/A, as it is sometimes called, is supplied in cylinders which are filled with a porous substance The pores in the filling material divide the space into a number of small compartments which prevent sudden decomposition of acetylene throughout the whole mass, should it start inadvertently by local heating The pores are completely filled with acetone in which the acetylene is dissolved under pressure At atmospheric pressure and temperature acetone will dissolve about 25 times its own volume of acetylene, and at 15 atmospheres this is increased to about 375 times its own volume It should be noted that acetylene cylinders should never be discharged at a rate which will empty them in less than 5 hours as this will result in acetone coming out along with the gas The flame temperature will also come down If higher discharge rates are required, cylinders should be coupled together depending on the requirements.

It should also be noted that an acetylene cylinder should always be stored and used in an upright position to prevent the escape of acetone when the gas is drawn off.

3.3.2 *Generated Acetylene* — Acetylene generators can be divided into two main types, namely, carbide-to-water and water-to-carbide. Large plants generally work on the first system, and a typical section of such a generator is shown in Fig. 3.1 (*see also* Fig. 2.5)

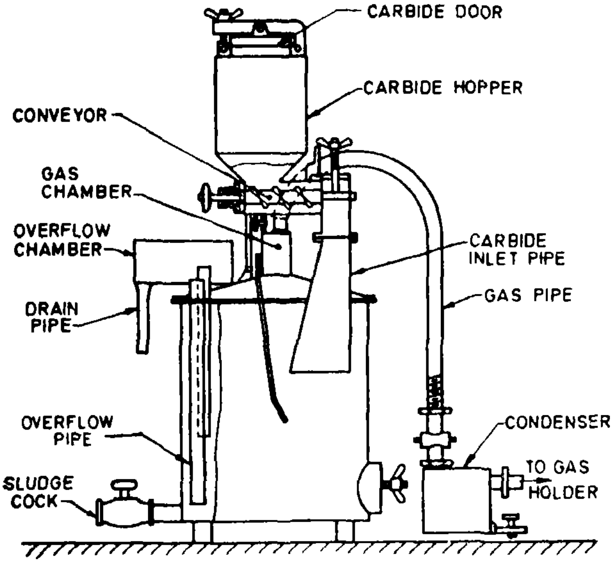


Fig. 3.1 Typical Carbide-to-Water Generator

The carbide, which is usually specified by the maker of the generator to pass a certain size mesh, is charged into the carbide hopper and fed into the lower chamber by some form of conveyor at a rate appropriate to the requirement. The lower chamber contains a large bulk of water with which the carbide reacts.

The smaller and portable generators usually work on the second system, in which the carbide is contained in a reservoir sub-divided into a number of small compartments. Water controlled by a float valve is fed into the first compartment and the acetylene which is generated is collected in a gas bell which rises and thus cuts off the water supply. A section of such a generator is shown in Fig. 3.2 and it will be noted that the carbide container is completely surrounded by water. This serves to absorb the heat generated by the reaction between the carbide and the water and thus helps to keep the gas delivered cool and pure. *As shown in Fig 3.2, carbide container should always be used half-full.*

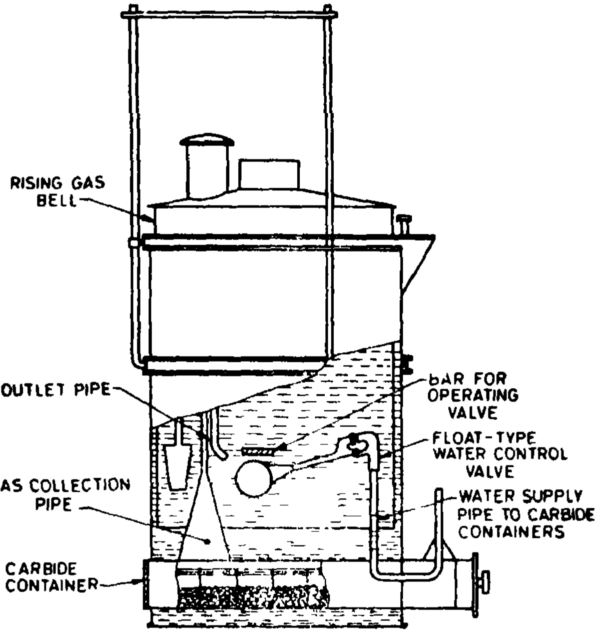


FIG. 3.2 TYPICAL WATER-TO-CARBIDE GENERATOR

Acetylene from the generator should be drawn through a hydraulic back pressure valve. Figure 3.3 shows the arrangement of a typical hydraulic valve.

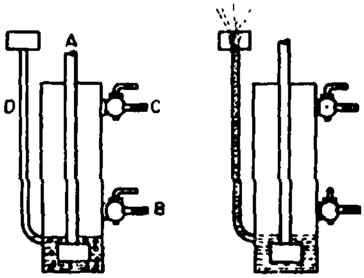


FIG. 3.3 HYDRAULIC BACK PRESSURE VALVE

The gas from the generator after passing through a purifier enters the valve at *A*. The body of the valve is filled with water to the level of the first water level cock *B*. When the blowpipe is functioning satisfactorily and the gas flowing normally tap *C* is opened and the gas passes direct from the entry pipe *A* through the body of the valve out through *C*. If, however, the nozzle of the blowpipe becomes obstructed or there is a backfire causing an increase in pressure in the acetylene hose that increase of pressure is communicated into the body of the valve thus forcing down the level of the water causing some of it to go up the entry pipe *A*, while the vent and filling pipe *D* is uncovered, allowing the results of any backfire to be exhausted to the atmosphere. As some water is displaced when a backfire occurs, the water level should be 'topped up' after a backfire before the valve is put into use again. The valve is no safeguard at all unless it is properly filled with water, and this should be attended to every morning as, apart from backfires, a water loss is sure to occur due to evaporation. The entry pipe *A* is usually provided with a valve and this should be shut when the plant is not operating. It must be shut also when the valve is being 'topped up' with water.

3.4 Oxy-Acetylene Welding Outfits

3.4.0 Generally oxy-acetylene outfit consists of the following:

High Pressure Outfit (*see* Fig. 3.4)	*Low Pressure Outfit* (*see* Fig. 3.5)
a) Supply of oxygen in cylinders.	a) Supply of oxygen in cylinders.
b) Supply of acetylene in cylinders.	b) Supply of acetylene from generating plants.
c) Blowpipe with necessary nozzles.	c) Injector type blowpipes, with necessary welding heads complete.
d) Oxygen pressure regulator.	d) Oxygen pressure regulator.
e) Acetylene pressure regulator.	e) Hydraulic back pressure valve.
f) Two lengths of canvas-rubber hose.	f) Two lengths of canvas-rubber hose.
g) Set of spanners and spindle key.	g) Set of spanners and spindle key.
h) Welding goggles and spark lighter.	h) Welding goggles and spark lighter.
j) Welding rods.	j) Welding rods.
k) Welding fluxes.	k) Welding fluxes.
m) Trolley for accommodating complete equipment and cylinders.	

3.4.1 *Welding Blowpipes* — A welding blowpipe is of simple construction. It consists of the following:

a) A handle with inlet connections for acetylene and oxygen and with control valves to control the flow of gases,

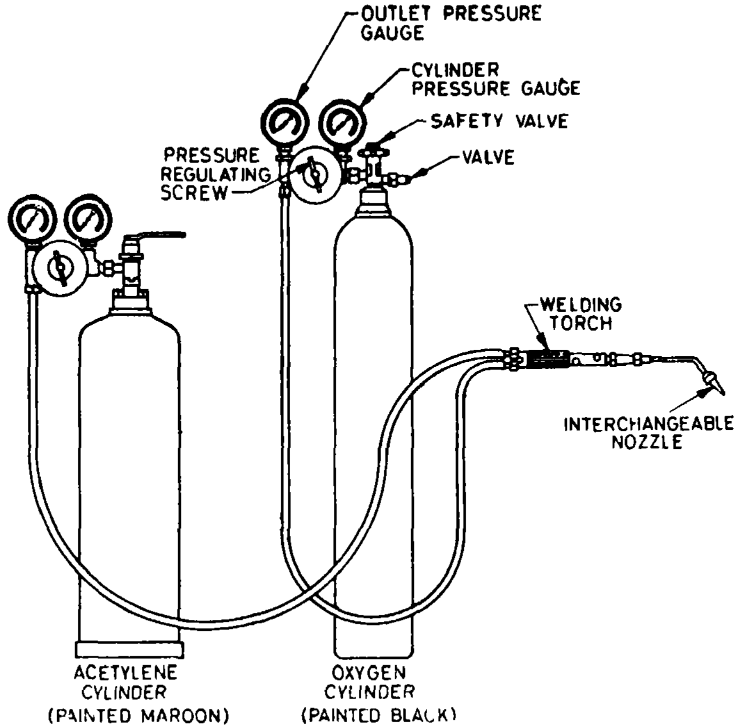


Fig. 3.4 High Pressure Oxy-Acetylene Welding Outfit

b) A device (injector or mixer) for mixing the gases in required proportions — gases coming from the control valves get mixed in this device, and

c) Neck fitted with nozzle — mixed gases pass through the neck, come out of the nozzle and are ignited to produce the flame

There are two types of blowpipes (*see also* IS 7653-1975*) — high pressure and low pressure The main difference is that the low pressure blowpipe is of the injector pattern while the high pressure blowpipe is of the non-injector mixer pattern *A low pressure blowpipe can be used with either a high pressure or a low pressure system, but the high pressure blowpipe can only be used with a high pressure system and must not under any circumstances be coupled to a low pressure system.*

The function of the injector in a low pressure blowpipe is to cause the oxygen passing through the blowpipe to suck a proportionate quantity of

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*Specification for manual blowpipes for welding and cutting.

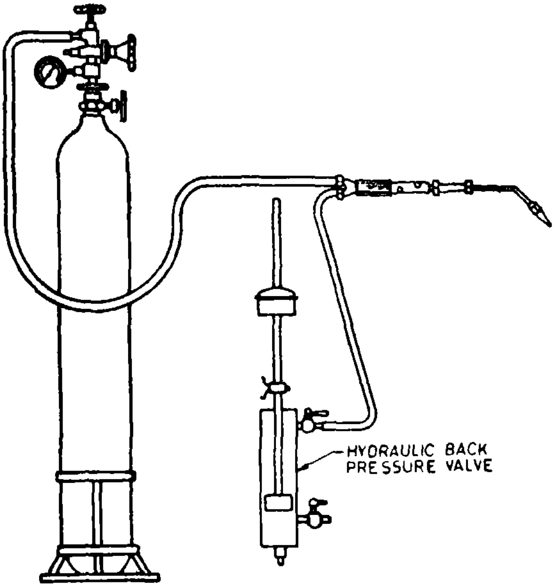

FIG. 3.5 LOW PRESSURE OXY-ACETYLENE WELDING OUTFIT

acetylene from the low pressure acetylene supply. In the case of high pressure blowpipe both gases are supplied to the blowpipe from the pressure regulators at appropriate pressures. A mixer arrangement within the blowpipe ensures a thorough mixing of the two gases before they arrive at the nozzle.

In low pressure system the size of the injector varies with the size of the nozzle. A low pressure blowpipe should, therefore, have a complete range of injector sizes corresponding to the range of nozzle sizes. In order to facilitate this and to avoid confusion, low pressure blowpipes are normally provided with a range of welding heads with nozzles on one and the corresponding injector at the other. The complete welding head should be charged every time the flame size is desired to be altered. In the case of high pressure blowpipes only nozzle or tip, as it is sometimes called, is required to be charged.

High or low pressure blowpipes are manufactured in a range of sizes to suit the various job requirements. A blowpipe when fitted with a particular nozzle is required to be used at gas pressures recommended by the manufacturer. Pressure settings for oxygen and acetylene in case of high pressure blowpipe and oxygen in case of low pressure blowpipe should, therefore, be made according to the recommendations of the manufacturers. In Fig. 3.6 has been shown the operating principles of high and low pressure blowpipes.

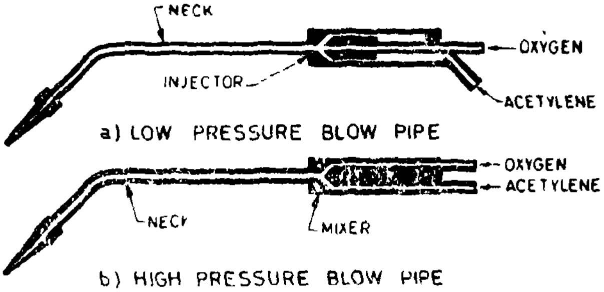

FIG. 3.6 OPERATING PRINCIPLE FOR LOW AND HIGH PRESSURE BLOWPIPES

3.4.2 *Pressure Regulators* — Pressure regulators for oxygen and acetylene are similar in construction although the pressure control range will be different — acetylene being generally used at a considerably lower pressure than oxygen. The pressure in a dissolved acetylene cylinder (16 kgf/cm^2 approx) is generally one-eighth of the pressure of the gas in an oxygen cylinder (136·4 kgf/cm^2). The principle of operation of a typical regulator is shown diagrammatically in Fig. 3.7.

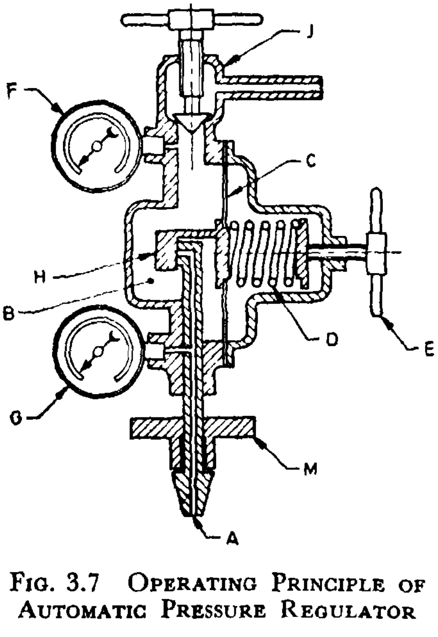

FIG. 3.7 OPERATING PRINCIPLE OF AUTOMATIC PRESSURE REGULATOR

High pressure gas passes from the compressed gas cylinder outlet valve via the passage *A* to the valve *H*, which is connected to the diaphragm *C*. The spring *D* can be compressed by the adjusting screw *E*. The accumulation of gas pressure in the chamber *B* tends to force the valve on to its seat while pressure on the spring *D* tends to push the valve off the seat. Therefore, the pressure of gas issuing from the outlet connection *J* depends upon the pressure exerted by the spring *D* in order to overbalance the pressure on the *B* side of the diaphragm, thus causing the valve *H* to open corresponding to the compression of spring *D*. A stoppage of gas at the outlet *J*, for instance, by shutting off the valve on the blowpipe causes pressure in the chamber *B* to accumulate until it overbalances the pressure exerted by the spring *D*, thus closing the valve *H*. The pressure of the gas in the compressed gas cylinder is recorded on gauge *G* and the working pressure on gauge *F*.

The diagram shown in Fig 3.7 is schematic only and shows the working principle of a regulator. The internal arrangement of different types of regulators will vary considerably (*see also* IS 6901-1973*).

The regulator shown in Fig 3.7 represents what is known as single stage regulator. There is another type of regulator called two-stage regulator which consists of two sets of diaphragms, and pressure reduction is affected in two stages. The first-stage reduction is pre-set by the regulator manufacturer and, therefore, always reduces to a certain non-variable pressure which passes from the first stage by a passage represented by the outlet connection *J* to the second stage, the pressure adjusting screw of which would be adjustable by the user in order to get the gas at the desired outlet pressure. In comparison to single-stage regulator, a more steady and accurate pressure control is obtainable from a two-stage regulator.

Besides regulators meant for use on cylinders, special regulators are also available for use with piped supply of gases. As the pressure of the gases in the pipeline system is much lower than the compressed gas pressure in the cylinder, these regulators are designed to work at lower inlet pressure.

3.5 Assembly of Equipment

3.5.1 *High Pressure Equipment*

a) Stand both cylinders vertically. Oxygen cylinders are painted BLACK. Acetylene cylinders are painted MAROON.

b) Care should be taken to see that all connections on the cylinder valves and regulators are free from oil and grease.

c) Open the valve on oxygen cylinder momentarily with a standard cylinder key and then close. This is called ‘ Snifting ’. This operation is necessary to dislodge any dirt or obstruction in the cylinder valve.

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*Specification for pressure regulators for gas cylinders used in welding, cutting and related processes

d) Repeat the same operation as in (c) for acetylene valve also.

e) Connect oxygen regulator (painted BLACK) to the oxygen cylinder valve remembering that the cylinder valve outlet and oxygen regulator connections have right-hand threads.

f) Acetylene regulator (painted MAROON) is then connected to the acetylene cylinder valve. The connections in this case have left-hand threads.

Note — While tightening the regulator on to the cylinder valves the correct spanner supplied for this purpose should be used and no excessive force applied The joints must be tested with soap solution for gas-tightness.

g) Connect the hoses, red hose for acetylene and black hose for oxygen, to regulator outlets using the correct spanner provided for this purpose without using undue force, but making sure that the joints are gas-tight. It should be remembered that oxygen connections are right-handed and acetylene connections are left-handed. Before attaching the hose to the regulator or blowpipe it should be blown for removing dust or dirt and to remove chalk when the hose is new. *Oxygen shall not be used for this purpose.*

Connect the other ends of the two hoses to the blowpipe, the acetylene and oxygen hoses to their respective connections.

Note — Before connecting the hoses to the regulator and the blowpipe, a hose connection consisting of a nut and nipple, is fitted to the end meant for connection to the regulator A hose clip of correct size should be used to tighten this joint in order to make it leak-proof. The other end of the hose meant for connection to the blowpipe can also be fitted with nut and nipple connections, but it is recommended that suitably designed backfire preventive devices are connected to this end. Such a device allows uninterrupted flow of gas from the hose to the blowpipe at the recommended working pressure, and also prevent the backflow from the blowpipe to the hose in case of backfire. Here again, a hose clip is used on the joint for making it leak-proof. Oxygen hoses are fitted with right-hand connection and nut and hose protector, whereas acetylene hoses are fitted with left-hand connection and nut and the nozzle of backfire protective device.

h) Depending on the job requirement, appropriate size recommended by the manufacturer of blowpipe should be fitted to the blowpipe.

j) Open the cylinder valves slowly using cylinder key giving a full one turn of the cylinder valve spindle.

k) Open the oxygen control valve on the blowpipe and set the working pressure at the regulator by means of the pressure adjusting screw. The pressure setting should be according to recommendation of the manufacturer of the blowpipe. Close the oxygen control valve.

m) Set the pressure for acetylene flow at the acetylene regulator in a similar manner.

n) Test all connections for leaks with soap water. *Never test leaks with a lighted match.*

p) Open the acetylene control valve on the blowpipe, wait for a few seconds until the hoses are purged of all air and then light the gas mixture by means of a spark lighter. *Never use match for lighting the gas.* Reduce or increase the acetylene supply by means of the control valve on the blowpipe so that the flame just ceases to smoke.

q) Turn on the oxygen by opening the blowpipe control valve and adjust it so that a neutral flame is obtained.

The blowpipe is now adjusted for welding and work may be commenced. For certain jobs instead of a neutral flame, an oxydizing or a reducing flame may be required. For such jobs the flames should be correctly adjusted before the job is commenced. On completion of the job proceed as follows:

a) Turn off the acetylene first by shutting the blowpipe control valve and then oxygen.

b) Close the cylinder valves.

c) To release the pressure in the hose, open oxygen valve and after the gas flows out, close it. Follow the same procedure for acetylene valve also.

d) After the pressure is released unscrew the pressure adjusting screws on the regulators.

NOTE — *In case of a backfire both oxygen and acetylene control valves on the blowpipe should be closed quickly — oxygen first and acetylene next. If necessary, pressure adjusting screws may be unscrewed and cylinder valves closed remembering that this operation should be done quickly — oxygen first, acetylene next.*

Recommended operating conditions are provided by all manufacturers of blowpipes and these should be followed. Given below is a table showing the appropriate consumptions of gases for welding various steel thicknesses for a typical high pressure blowpipe:

Mild Steel Plate Thickness mm	*Approximate Consumption of Each Gas* l/h
0·80	28
1·25	56
1·6	85
2·5	142
3·15	200
4	280
5	370
6·3	510
8	710
10	990
12	1 280
20	1 550
25	2 000
Over 25	2 550

NOTE — A low pressure blowpipe can also be used with dissolved acetylene from cylinders. In this case the acetylene pressure should be set at about 0·14 kgf/cm^2. Oxygen pressure should be as recommended by the maker of the blowpipe.

3.5.2 *Low Pressure Equipment*

a) Make sure that the generator is charged with sufficient quantities of carbide and water.

b) Fill the hydraulic back pressure valve with water up to the desired level.

c) Open the oxygen cylinder valve momentarily and ' Snift ' it.

d) Make sure that there is no oil and grease on the cylinder valves or regulator connections.

e) Fit the regulator on the oxygen cylinder valve and attach a rubber hose from the regulator to the blowpipe as described in the case of high pressure equipment.

f) Fit the hose from hydraulic valve to acetylene connection in the blowpipe.

NOTE - A blowpipe for use with an acetylene generator should always be a low pressure injector type blowpipe. *High pressure blowpipe SHALL NOT BE used with an acetylene generator.*

g) Attach the injector head of appropriate size to the blowpipe. Remember that in case of low-pressure blowpipe the entire head comprising of the injector, the neck and the nozzle, is interchangeable.

h) Clear the acetylene system off air by allowing acetylene from the generator to pass freely into the atmosphere for several minutes. Where the generator is in an enclosed place, it is important that the discharge is outside the building in an open space away from flame, naked lights, etc.

j) Before opening the oxygen cylinder valve ascertain that the pressure regulating screw of the oxygen regulator is screwed full out, that is, to no pressure. Then open the cylinder valve slowly and adjust the regulating screw pressure in accordance with manufacturers' recommendations.

k) Test all connections for leaks with soap water.

m) Open the oxygen control valve on the blowpipe, then the acetylene valve and ignite the gases with a spark lighter. Never use match sticks for the purpose.

n) Adjust the flow of oxygen by means of the control valve to obtain the desired flame.

Welding may now be commenced. On completion of the job proceed as follows:

a) Close the blowpipe acetylene control valve, then the oxygen valve.

b) Close the oxygen cylinder valve, release pressure in hose by opening oxygen valve in the blowpipe, and unscrew the pressure regulating screw on the regulator.

c) Shut the outlet on the hydraulic back pressure valve and shut off the generator as instructed by the maker.

The acetylene generators are normally automatic in action and do not need any shutting off when no further gas is required.

3.5.3 *Operating Conditions* — The operating conditions for gas welding blowpipes vary from manufacturer to manufacturer. Therefore, the data furnished by the manufacturer regarding nozzle sizes, working pressure, gas consumption, etc, for welding various thicknesses should always be strictly followed.

3.5.4 *The Cutting Blowpipe* — A useful adjunct to any oxy-acetylene welding plant is an oxy-acetylene cutting blowpipe used for cutting steel and cast iron. Figure 3.8 shows the operating principle of an oxygen cutter. A cutting blowpipe, like a welding blowpipe, utilizes oxygen and acetylene to produce heat but the heat is used to preheat the area adjacent to the line of cut. The nozzle is, therefore, so constructed as to obtain an annular flame. The cutting oxygen passes through an orifice in the centre of the nozzle.

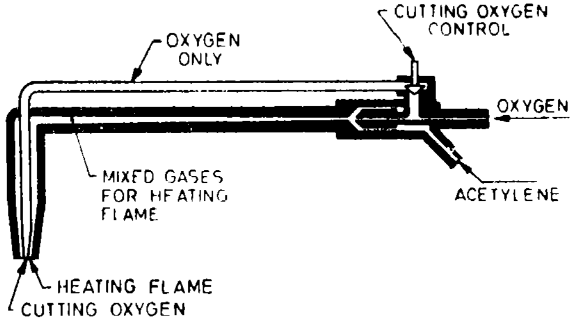

FIG. 3.8 OPERATING PRINCIPLE OF OXY-ACETYLENE CUTTING

For oxygen cutting, besides acetylene, other fuel gases may also be used. Liquefiable petroleum gas, commonly known as LPG, is now available in most of the places in India and is being increasingly used for oxygen cutting. Cutting nozzles operating with LPG are different from the nozzles used with acetylene as fuel gas.

3.5.5 *Oxy-Acetylene Gouging Blowpipe* — Oxy-acetylene gouging blowpipe resembles an ordinary cutting blowpipe but is provided with a nozzle which gives a low velocity central cutting jet. This jet can be used to remove defective welds in the preparation of plate edges for subsequent welding.

3.5.6 *Flame Cleaning Blowpipe* — Oxy-acetylene flame cleaning blowpipe makes use of a high temperature brush like flame for descaling steel surfaces.

3.5.7 *Air-Acetylene Blowpipe* — This equipment although not normally used for welding, is capable of producing an intensely hot flame which can be used for soldering, lead burning, brazing, etc. The air necessary for combustion is obtained by the injector action of the burner. Acetylene is supplied from a cylinder using a regulator in the usual manner.

Air LPG torches are also being used for such applications as brazing, heating, etc.

3.5.8 *Oxygen-Cutting Machines* — Oxygen cutting machines are comparable with machine tools and are capable of making high quality cuts which often require no further machining. Figure 3.9 illustrates a portable straight-line cutting machine where the cutter is mounted on a motorized tractor, the tractor usually moving on a track. Such cutting machines are adaptable to automatic circle cutting also by attaching a radius bar. A profile cutting machine which cuts intricate shapes is illustrated in Fig. 3.10.

3.5.9 *Miscellaneous Accessories* — The following accessories are normally used with oxy-acetylene equipment:

a) *Hose* — Hoses are used for conveying the gas from the cylinders and generators to the blowpipe. There are two specifications for welding hoses namely, IS : 3572-1968* and IS : 447-1968†. Three sizes of hoses are generally used: 5, 8 and 10 mm. It is recommended that hoses conforming to Indian Standard specifications are used in connecting welding equipment.

b) *Hose Clips* — Use of clips is the safest way of fixing hoses to its connections. It is dangerous to use wire for this purpose. Two sizes of hose clips are generally available, one to suit 5 mm hose and the other for 8 and 10 mm hoses.

c) *Hose Connections and Nut* — For coupling standard lengths of hoses and for connecting hoses to regulators, suitable hose connections and nuts should be used. Oxygen nuts are screwed right-handed and have plain facets, the acetylene nuts are screwed left-handed and have notched facets. Hose connections are covered in IS : 6016-1970‡.

d) *Backfire Protective Device* — This is fitted at the inlet connection of the blowpipe. This device is also known as hose protector, hose check valve, etc.

e) *Spanners and Spindle Keys* — Regulator spanner, spindle keys and out-fit spanners should be as recommended by the manufacturer for oxy-acetylene welding and cutting equipment.

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*Specification for welding hose of rubber with braided textile reinforcement (*first revision*).

†Specification for welding hose of rubber with woven textile reinforcement (*second revision*).

‡Specification for hose connections for welding and cutting equipment.

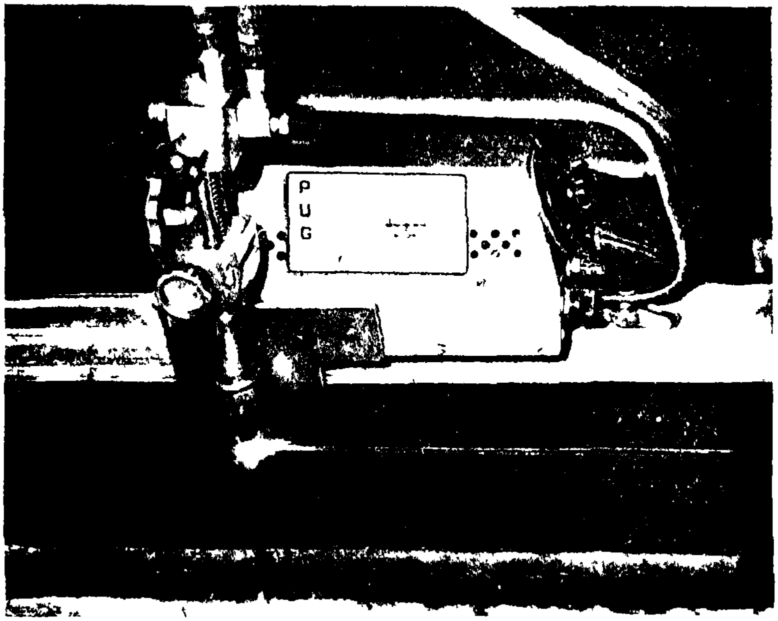

FIG. 3.9 CUTTING MACHINE

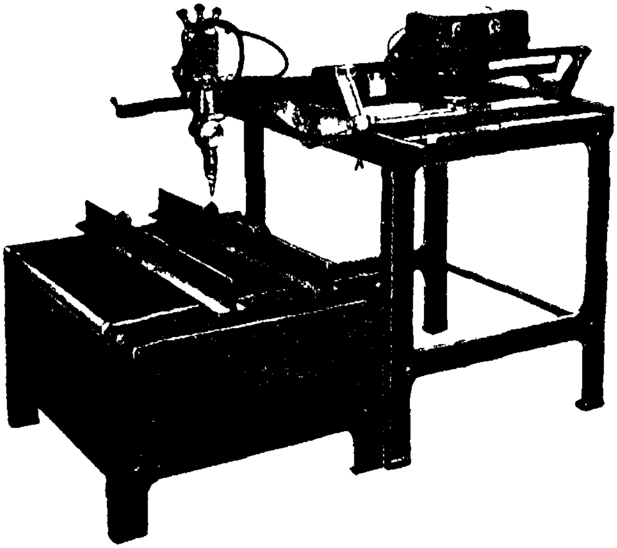

FIG. 3.10 PROFILE CUTTING MACHINE

f) *Welders' Goggles* — No welding or cutting operations shall be carried out without protecting the eyes with good quality goggles. The requirements for welders' goggles are specified in IS : 1179-1967*. The filters used in the goggles should be of good quality and provide protection to the eyes against glare, injurious radiation or sparks or hot particles of metals or a combination of these hazards. It is recommended that the goggles should conform to IS : 1179-1967* fitted with filters conforming to IS : 5983-1971†. Shades 3, 4a, 5 and 5a are recommended for light gas cutting and welding, while shades 6, 6a, and 7 are suitable for medium to heavy gas cutting including scraping and welding.

g) *Gloves* — Use of leather gloves during welding is recommended for protecting welders' hands from heat and radiation. IS : 2573-1963‡ covers the requirements of leather gloves for welders.

h) *Apron* — Recommended for protection of the operator from heat, flying sparks, molten metal, etc, during welding and cutting.

j) *Wire Brush* — Wire brush is a useful accessory for cleaning the welds.

k) *Cylinder Trolley* — Use of a suitably designed cylinder trolly is recommended for easy movement of cylinders and tools to the work site. It should be constructed to withstand hard wear and should accommodate one oxygen and one acetylene cylinder.

m) *Spark Lighter* — Spark lighter is a safe and convenient tool for lighting an oxy-acetylene flame.

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*Specification for equipment for eye and face protection during welding (*first revision*).

†Specification for protective filters for welding, cutting and similar operations.

‡Specification for leather gauntlets for welders

SECTION 4

SAFETY IN WELDING

4.1 General

In any sphere of activity, it is necessary to know and understand the sources of danger to ensure safety. In welding and allied processes there are certain easily defined sources of danger which should be constantly borne in mind.

In gas welding and cutting processes, combustible gas like acetylene, is used for obtaining high temperature flame. Acetylene is obtained commercially either from cylinders in which gas is compressed and dissolved in acetone, or in generators on the spot by the reaction of water on calcium carbide.

The person handling the gas cylinders, gas generators and blowpipes should be completely familiar with the correct procedures for handling the equipment safely Some of the essential precautions to be taken in the use of these equipments are given in the following paragraphs. Reference may be made to IS : 818-1968* for detailed rules and regulations.

4.2 Storage and Handling of Gas Cylinders

4.2.1 *Storage of Cylinders*

4.2.1.1 All cylinders used for storage and filling of compressed gases shall be constructed and maintained in accordance with the requirements specified in the *Gas Cylinder Rules, 1910*, issued by the Government of India.

4.2.1.2 Compressed gas cylinders shall be painted as specified in IS : 4379-1967†. The following colour code for the more commonly used gases are as follows:

Gas	*Colour Coding According to IS : 4379-1967†*
Oxygen	Black
Dissolved acetylene	Maroon
Hydrogen	Red
Coal gas	Red
Liquefiable petroleum gas	Red

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*Code of practice for safety and health requirements in electric and gas welding and cutting operations (*first revision*).

†Identification of the contents of industrial gas cylinders.

These cylinders shall not be repainted with any other colour than those specified above either by the users or the manufacturers

4.2.1.3 To avoid interchangeability of cylinder fittings, and the corresponding equipment, the screw threads used on combustible gas cylinders are left-handed and those on non-combustible gas cylinders are right-handed.

4.2.1.4 The place used for storing of gas cylinders shall be well ventilated and the cylinders shall be protected from direct exposure from extreme cold or heat, frost, direct sun's rays, space heaters, etc

4.2.1.5 Gas cylinders should not be stored on wet soil to prevent rusting

4.2.1.6 Empty cylinders should be marked 'empty' or 'MT' and segregated from full cylinders They should be returned to the supplier with valve protection caps in place All valves should be closed

4.2.1.7 In storing or in use, dissolved acetylene cylinders should always be kept upright (the valve pointing upwards)

4.2.1.8 Oxygen cylinders may be stored horizontally but the stock should not be more than four high

4.2.2 *Handling of Cylinders*

4.2.2.1 If cylinders are accidentally exposed to heat the gas content will increase in pressure and dangerous condition may arise For safety, therefore, cylinders should be kept away from sources of heat such as furnace, stoves, boilers, radiators and also away from combustible material and blowpipe flames

4.2.2.2 Oil or grease should not be used with any gas cylinder or equipment fittings used for gas welding or cutting operations Oil or grease ignites violently in the presence of oxygen, and when the gas is under pressure, an explosion may occur

4.2.2.3 Dirt, grit and loose soil should not be allowed to enter the cylinder valves

4.2.2.4 In case of a tight fitting equipment, the cylinder valve should not be lubricated with oil or grease A little soap solution (free from oil or grease) in water may solve the problem

4.2.2.5 Cylinders should not be allowed to drop from a height or collide violently with each other In ferrying cylinders across the shop floor, magnetic chuck cranes should not be used A better method is to use a cradle or a properly fitted rope sling

4.2.2.6 Oxygen has no smell and it supports combustion Clothing soaked in oil or grease will catch fire even from sparks and should this come in contact with oxygen, the severity of the combustion will intensify.

Dissolved acetylene and liquefiable petroleum gas have their characteristic smells and will ignite even from a spark

4.2.2.7 In the event of a dissolved acetylene cylinder catching fire, the following safety measures should be taken

a) Shut valve, detach regulator or other fitting, take cylinder out of door into open space immediately

b) Immerse the cylinder in water or spray water continuously on the cylinder and simultaneously open the cylinder valve spindle and let the fire die out, and

c) Inform supplier immediately

4.2.2.8 The cylinder valve spindles of all gas cylinders should be opened slowly

4.3 Handling *of* Acetylene Generators

4.3.1 Acetylene generators properly designed and incorporating all safety devices should be used (for further details, *see* Section 3)

4.3.2 Large size stationary generators should be housed in well-ventilated generator houses constructed of non-combustible material Generator house shall be open to authorized persons only

4.3.3 Installations of generators inside buildings shall be restricted to buildings not exceeding one storey in height and they shall be enclosed in a separate room of suitable size One wall of an inside generator room shall be an exterior wall

4.3.4 Portable acetylene generators should be used, cleaned, and recharged in a well-ventilated place and away from naked flame, fire or combustible material

4.3.5 When recharging or cleaning generators of the ' dipping type ' (carbide-to-water type), the basket should always be cleaned and fitted with new carbide A partially spent charge should not, in any circumstances, be replaced in the generator

4.3.6 When removing pieces of carbide which may have become wedged in the feed mechanism of ' carbide-to-water ' type generator, the creation of spark by rough handling should always be avoided Wooden instrument should preferably be used to dislodge the pieces

4.3.7 Acetylene generators should be periodically checked by competent people

4.3.8 Before any repair work is undertaken, it should be made certain that the generator is completely free of gas and the whole generator should be filled up with water to drive the gas out

4.3.9 Only approved amount of carbide should be used in the hopper/basket of the generator. Excess charge should be avoided.

4.3.10 Hydraulic back pressure valves or non-return valves of the approved types shall be only used in the line between the generator and welding points.

4.3.11 The water level of the hydraulic back pressure valve should be checked daily and topped up. The valve should be overhauled periodically.

4.4 Storing of Calcium Carbide

4.4.1 The storage of calcuim carbide exceeding 12·7 kg by weight is governed by:

a) The Carbide of Calcium Rules, 1937; and

b) The Petroleum and Carbide of Calcium Manual, 1950.

Reference should be made to these publications before arranging to store bulk quantities of calcium carbide.

4.5 Use of Gas Welding and Cutting Equipment

4.5.1 Equipment for use with any one type of gas should not be used with other gases. All equipment intended for use on combustible gases are fitted with left-hand screw connections. That, however, does not mean that a regulator meant for use on hydrogen may be used on dissolved acetylene as hydrogen is stored in cylinder at a much higher pressure than that of dissolved acetylene.

4.5.2 The canvas and rubber hose used with welding and cutting equipment shall be of the approved standard and colour (*see* IS : 447-1968* and IS : 3572-1968†). The practice is to use black colour hose pipe for oxygen and compressed air, and red colour hose for fuel combustible gases.

4.5.3 A blowpipe of the injector type intended for use with low pressure shall not be used in connection with high pressure acetylene unless a suitable control valve is fitted. A blowpipe of the non-injector type intended for use with high pressure shall not be used with low pressure acetylene.

4.5.4 All blowpipes and other apparatus shall be dismantled and cleaned internally at regular intervals, preferably by the makers. The apparatus shall be maintained in proper working order.

4.5.5 Accumulation of slag on the blowpipe tip shall be frequently removed. No attempt should be made to alter or clean the blowpipe tip by a hard metal reamer; only hard wood sticks or soft brass wire shall be used for this purpose.

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*Specification for welding hose of rubber with woven textile reinforcement (*second revision*).

†Specification for welding hose of rubber with braided textile reinforcement (*first revision*).

4.5.6 Gas cylinders should never be used as work support nor should the welding blowpipe flame be allowed to come in contact with the cylinders. A lighted blowpipe shall not be suspended from the cylinder neck.

4.5.7 All equipment should be operated with the correct pressures of gases and the regulators should be capable of giving the required flow.

4.5.8 All welding and cutting equipment should be maintained in clean and satisfactory operating condition and all threaded connections should be kept tight. Leak in any component should be immediately checked and remedied.

4.5.9 Unqualified and unauthorized persons should not attempt to repair any welding and cutting equipment.

4.5.10 If coal-gas is used, the delivery line should be fitted with a recommended type of non-return valve.

4.6 Use of Gas Welding and Cutting Accessories

4.6.1 The welding hose in use should be frequently checked to detect any leak, sharp cut, etc

4.6.2 Hose pipes should be firmly attached to the equipment with recommended type of hose clips

4.6.3 To attach the hose pipes on to the equipment, use should be made of correct type of hose fittings.

4.6.4 The lengths of hose pipes in use for oxygen and fuel gas should be equal and the excess length should not be coiled round the gas cylinders in use.

4.6.5 It is dangerous to use high copper (about 70 percent) alloy for fittings coming in contact with acetylene gas.

4.6.6 Recommended type of cylinder and spindle key should be used. While opening the cylinder spindle, excess leverage should be avoided.

4.7 Protection of Eyes

4.7.1 Goggles with lenses of approved tint should be worn to protect the eyes from sparks and avoid eye strain The recommended type of lenses are those that conform to IS · 5983-1971*. The goggles should conform to IS : 1179-1967† and the frame should be of the closed type. The filter lenses should be protected from flying sparks by suitable plain glasses. When spoilt, the plain glasses should be replaced.

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*Specification for protective filters for welding, cutting and similar operations.

†Specification for equipment for eye and face protection during welding (*first revision*).

4.7.2 The goggle frame should be manufactured from a material or materials which do not cause irritation to the skin of the operator.

4.8 Ventilation — Ample means of thorough ventilation should be constantly maintained in welding and cutting shops. Special care should be taken to force ventilate a confined space where gas welding and cutting is being done. Further, reference should be made to the *Factories Act, 1948* for detailed information on ventilation.

4.9 Protection of Clothing

4.9.1 The clothing worn by a welder should be such that it will give him protection from hot metal and flying sparks. The clothing should have as few pockets as possibles as sparks, hot metal particles, etc, may get lodged in these and cause burns. It is preferable not to roll up sleeves.

4.9.2 It is preferable to use shoes instead of open type footwear.

4.9.3 Except for light welding work, all welders should use protective leather gloves. For heavy welding and welding inside surface, the welder should use flameproof asbestos gloves.

4.9.4 Where there is danger of falling objects, the operator should use protective shockproof helmet.

4.10 Prevention of Fire

4.10.1 Sparks from welding and particularly from cutting can travel a long distance. It is, therefore, recommended that such work should be carried out away from flammable materials. (Reference may be made to IS : 3016-1965*.)

4.10.2 Wooden floors are source of danger, and should be avoided. If unavoidable, these floors should be covered by sheet metal.

4.10.3 Fire extinguishers and sand should be kept ready. In case of emergency, water may be sprayed to flood the place.

4.10.4 Should it be necessary to carry out welding or cutting operations in the vicinity of existing wooden structures, special precautions should be taken to protect such a structure.

4.10.5 Cutting and welding should not be done in a place which is in proximity of a room or store containing flammable vapours, liquid, dust, etc.

4.10.6 Welding should not be carried out in or around a painting installation.

4.10.7 Gas cylinders should not be allowed to come in contact with electric cables and electrical conductors.

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*Code of practice for fire precautions in welding and cutting operations.

4.11 Working on Staging, Scaffolding, etc

4.11.1 If it is necessary to work on stagings, scaffoldings, etc, adequate protection should be taken to prevent the operator from falling.

4.11.2 The operator should be provided with a life line or a safety belt.

4.11.3 Hand rail or rope line should be provided around the staging.

4.11.4 The space below the operation limits should be adequately fenced off and a note of warning should be displayed.

4.11.5 Gas cylinders in use or stored on site should be protected from flying sparks and falling hot metal.

4.12 Welding Tanks or Vessels

4.12.1 No attempt should be made to preheat or weld jacketed vessels, tanks or containers or cored or hollow parts unless all precautions have been taken to remove the confined air or residual gas.

4.12.2 A hollow vessel should first be drilled (for ventilation) before attempting to weld, otherwise the vessel may behave like an explosive object.

4.12.3 Any container used for storing volatile or flammable material should be thoroughly degassed before attempting to weld.

4.12.4 Empty containers of flammable material should not be used as job support.

4.12.5 A working notice should be displayed at the spot where this type of welding is being carried out.

4.13 Welding Inside a Boiler

4.13.1 In welding inside a boiler where the space is confined, the gas cylinders should be kept outside, and the hose pipes in use should be properly checked for any cut or leak. Forced ventilation should be maintained for the operator by the use of an exhaust/circulating fan; under no circumstances oxgyen should be used for this purpose. A bucket of water should be kept ready at hand for any emergency. In case of fire, the fire extinguisher used should be of the non-corrosive type and it should not give out toxic fumes.

4.13.2 A helper should be in attendance outside the boiler to render all assistance to the welder.

4.14 Working on Painted Surfaces

4.14.1 When burning of paint, prior to welding or cutting operation on painted surfaces, the operator should use a recommended inhalation mask. Similarly precaution shall be taken when working on galvanized parts.

4.14.2 Should nausea overpower the operator, he can get relief by drinking milk or light beverage.

SECTION 5

WELDING METALLURGY

5.1 General

Welding, while being the most versatile and adaptable of all joining methods, is a highly specialized process, requiring both skill and a thorough knowledge of the technicalities involved on the part of the welder.

Generally in all welding processes, external heat energy in some form or other is applied to raise both the joining faces and filler metal to the point of fusion or incipient fusion before the welding can take place. Therefore, the physical and metallurgical changes which take place in any metal or alloy when it is heated to the fusion point and allowed to cool from there, assumes great importance in the welding process.

A welders' ability to produce a good sound weld will depend on his basic metallurgical knowledge regarding the behaviour and properties of methods and alloys when they are subjected to any particular thermal cycle.

It is intended in this section to discuss briefly the basic metallurgical principles involved in welding specially with regard to gas welding which covers a very vast field of metal joining processes involving a great number of metals and alloys.

5.2 Classification of Materials

As illustrated in Fig. 5.1, engineering materials may be classified into two basic groups:

a) Metallic, and

b) Non-metallic.

Metallic materials may again be divided into two groups — ferrous and non-ferrous, as shown in Fig. 5.1.

5.2.1 *Ferrous Materials* — These have iron as their base. Examples are cast iron, wrought iron, mild steel, carbon steel, alloy steel, etc.

All ferrous materials, with the exception of wrought iron, are derived from pig iron which is the raw material obtained by the reduction of iron ore in the blast furnace. These are essentially alloys of iron and carbon containing manganese, silicon, etc, and incidental impurities such as sulphur, phosphorus, etc. All these have a direct bearing on the physical properties of the metal and also affect their weldability.

Alloys of iron and carbon containing up to 1·8 percent carbon are generally known as steels and those which contain more than 1·8 percent carbon are generally known as cast iron. There is, however, no clear cut line of demarcation between these two.

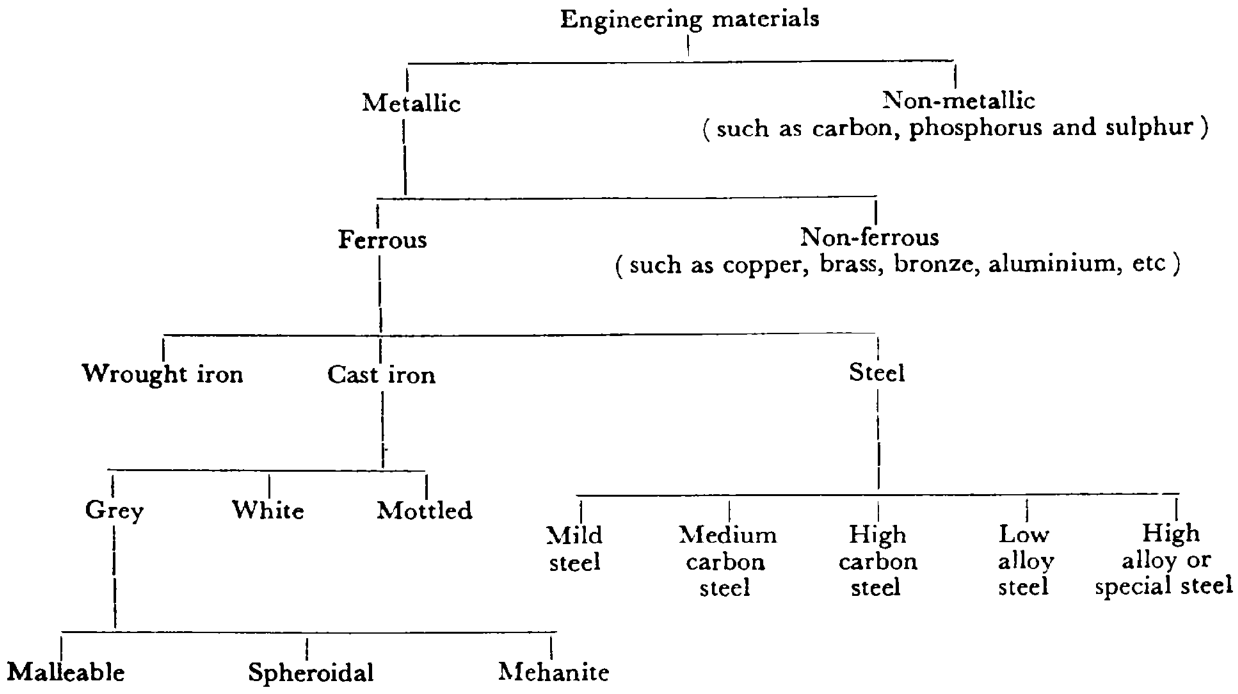


FIG. 5.1 CLASSIFICATION OF ENGINEERING MATERIALS

Steels used in industries may be divided into two groups, namely, plain carbon steels and alloys steels The properties of carbon steels depend essentially on their carbon content while in the case of alloy steels the properties depend both on the carbon percent and also the presence and amount of one or more alloying elements such as nickel, chromium, molybdenum, vanadium, tungsten, etc, and the presence of increased percentages of manganese or silicon

In steels, the presence of alloying elements in small quantities improves in general their mechanical properties such as strength, toughness, hardness, etc Certain special properties such as resistance to heat, corrosion, shock or wear may be conferred on steels by the addition of suitable alloying elements in sufficiently large quantities The alloy steels, therefore, are further divided into

a) *low alloy steels which contain alloying elements, in small amounts* to improve their general mechanical properties, and

b) high alloy steels or special alloy steels which contain suitable alloying elements in large quantities to impart certain special properties to the steels to form austenitic, corrosion and heat-resisting steels, high speed cutting steels, air-hardening steels, etc

5.2.2 *Non-Ferrous Materials* — These are metals, other than iron based but iron may be present as an incidental impurity or minor alloying constituent

Non-ferrous metals are varied in nature and the behaviour and properties of non-ferrous metals are mostly different from one another Generally, the non-ferrous metals as well as their alloys are classified according to the base metal, such as

a) Copper and copper-base alloys, for example, brass and bronze,

b) Aluminium and aluminium-base alloys, for example, silicon-aluminium, duralumin, etc,

c) Nickel and nickel base-alloys, for example, monel,

d) Other non-ferrous metals and alloys, for example, magnesium, silver, etc, and their alloys

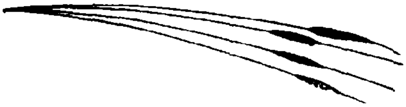
5.3 Identification of Metals — It is essential for the welder to be familiar with some rough and ready method of identifying metals in order to distinguish one from another There are various methods amongst which the spark test is most useful in the workshop The spark test is done by holding tightly a sample of metal on a grinding wheel and then observing the shape, colour and length of the streaks and sparks produced (*see* Fig 5 2)

5.4 Metallurgy of Steel — In order to understand the metallurgy of welding, a welder should have at least the basic knowledge of the following

a) The changes that occur in the structure of pure iron with rise in temperature;

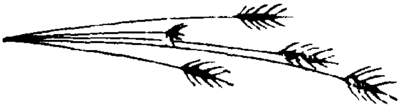
b) The effect of addition of carbon on the structural changes that occur in iron with rise in temperature;

WROUGHT IRON



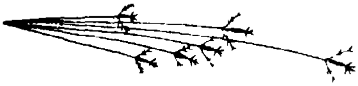
Long Yellow Streaks Broadening to a Leaf, Some Distance from the Grinding Wheel

MILD STEEL



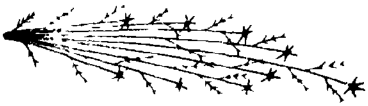
The Leaf Is Smaller and Gives Rise to a Number of Sparks, Some Sparks are Shorter

MEDIUM CARBON STEEL



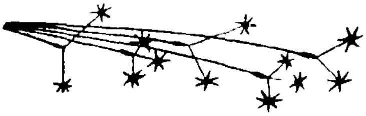
Very Small Leaf, Larger Sparks Nearer the Grinding Wheel

HIGH CARBON STEEL



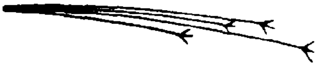
Streaks Less Bright, Profusion of Sparks Starting very Close to the Grinding Wheel, Complete Absence of Leaf

MANGANESE STEEL



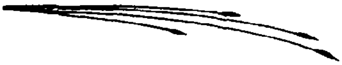
The Streaks Fork Before Forming Sparks

HIGH SPEED STEEL



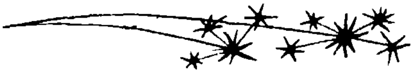
Faint Red Streaks Terminating in a Fork

STAINLESS STEEL



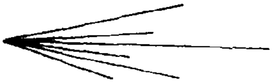
Bright Yellow Streaks Terminating in Pointed Ends

CAST IRON



Faint Red Streaks Terminating in Complex Bushy Sparks, Yellow in Colour

MONEL METAL



Faint Red Streaks Quickly Tailing Off

FIG. 5.2 SPARK TEST FOR IDENTIFICATION OF METALS

c) The changes that occur in the structure and constitution of iron-carbon alloys:
   1) with rise in temperature, and
   2) with different rates of cooling from temperature as met with during welding;

d) The mechanical properties of steels that have been cooled at different rates from temperatures as met with during welding; and

e) The effect of increase in carbon content on the mechanical properties of steels that are cooled very rapidly from high temperatures as met with during welding.

The above facts will be dealt with in an elementary way in the subsequent paragraphs.

5.4.1 Iron in its pure form as steel is basically an aggregate of small crystals which are oriented in a particular structure according to the temperature and constituents in the steel. The crystallographic structure of iron that exists in the room temperature is called α-iron. α-iron is also known as 'ferrite'. When the iron is heated from room temperature to higher temperature a transformation in the cystallographic structure takes place at 910°C. The iron in new crystallographic form is known as γ-iron. α-iron contains very little quantity of carbon in solution (0 025 percent, *Max*) while γ-iron can take up to 1·7 percent carbon in its crystal structure. Any carbon in excess of the solubility limit in steel for that particular structure and temperature is rejected from solution and forms a compound with iron, Fe_3C, which is known as 'cementite'.

5.4.2 The effect of addition of carbon in iron up to 0·83 percent is to lower its transformation temperature from 910°C to 723°C. When the steel contains more than 0·83 percent carbon the α-iron transforms to γ-iron on heating above 723°C and γ-iron again comes back to α-iron stage when cooled below 723°C (*see* Fig. 5.3).

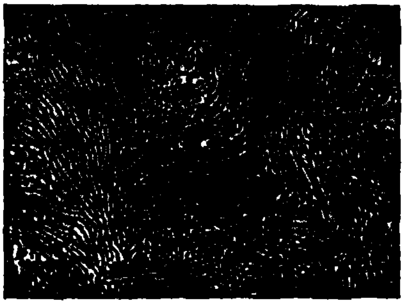


FIG. 5.3 PEARLITE

5.4.3 If a plain carbon steel of 0·4 percent carbon is seen under a microscope after proper preparation, the structure will consist of ferrite (α-iron) and alternate lamelae of ferrite and cementite known as pearlite (*see* Fig. 5.4). As the carbon percentage in the steel goes up the total amount of pearlite will increase. A steel containing 0·83 percent carbon will give a fully pearlitic structure. In all plain carbon steels when heated the α-iron changes to γ-form at the transformation temperature. As γ-iron dissolves carbon up to 1·7 percent, any carbon percent in iron below 1·7 percent will go into solution above transformation temperature. This solid solution of carbon in γ-iron is called ' austenite '.

Now during cooling austenite transforms back to ferrite and pearlite at transformation temperature. As already mentioned ferrite contains very little carbon. Most of the carbon present in the γ-iron solution will, therefore, form iron carbide and in the microstructure both ferrite as well as pearlite will be visible depending upon the percentage of carbon present.

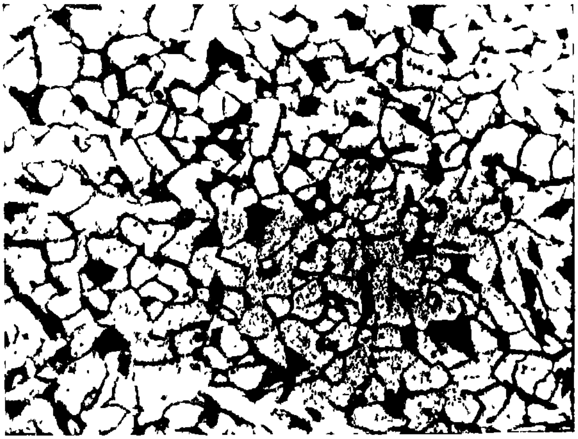


FIG. 5.4 FERRITE AND PEARLITE

5.4.4 When the austenite is cooled at increasing rates, the alternate layers of ferrite and cementite constituting the pearlite become finer and finer. The effect of this is to increase the hardness and strength of the steel so treated. When the cooling rate exceeds a particular value, a new structure entirely different from fine pearlite results. It is called ' martensite ' (*see* Fig. 5.5) and is the hardest constituent of steel and is very brittle.

5.4.5 As the carbon content in steel increases, a lesser rate of cooling is adequate to produce the hard martensitic constituent. In other words the tendency for the steel to become hard and brittle for a given rate of

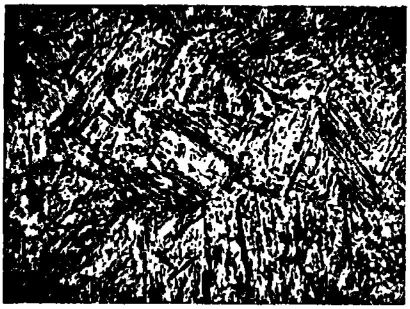


FIG. 5.5 MARTENSITE

cooling increases with the carbon content. Ordinary structural mild steel has sufficiently low carbon to prevent hardening under any condition of cooling. But, the medium and high carbon steels contain enough carbon to render the parent material extremely hard and brittle when cooled from welding temperature at ordinary rates of cooling as met with in practice. Under the usual conditions in welding shop, the rate of cooling is not only dependent on the difference in temperature between welding temperature and the room temperature, but also on the mass of the parent metal which conducts the heat away from the weld metal and the heat affected parent metal. So in the thicker sections the rate of cooling is high, that is, the tendency for the formation of hard constituent is increased.

5.5 Weldability — Weldability is a combined property of parent metal and filler metal. It may be defined as the capacity to produce a crack-free and mechanically satisfactory joint. In other words, it is the capacity of a metal to be welded under fabrication condition imposed into a specific suitably designed structure and to perform satisfactorily the intended service. Thus a metal should have good weldability in order to produce a sound and satisfactory joint. Weldability of a metal or alloy is determined by its chemical composition, mechancial properties and effect of welding on mechanical and/or chemical properties.

5.6 Welding of Steels

5.6.1 *Low Carbon Steels* — Steels with low carbon content normally from 0·08 to 0·3 percent constitute the major portion of the steels that are produced in the industry. Most steels that are rolled into plates, bars and sections come under this group. Normally preheating of the parent metal is not required in the case of steel containing less than 0·15 percent carbon and if the section is not very heavy.

The low carbon steel having carbon percentage near the upper limit if cooled rapidly will give hard and less ductile martensite but the slow cooling of the plate or the weld deposit will give reasonably ductile, tough property in the welding zone. Oxy-acetylene process, however, for all practical purposes will be used in thin sections.

5.6.2 *Medium Carbon Steels*—Medium carbon steel normally contains 0·3 to 0·6 percent carbon. These are readily hardened when heated to above transformation temperature and allowed to cool rapidly. Thus it forms a hard and brittle hard zone next to the weld metal when cooled rapidly. The heat affected zone may develop crack under restraint. Preheating to about 180 to 350°C of the plates or parts to be welded is normally advisable and this produces crack free sound joints. The possibility of carbon pick up by the weld metal during welding of medium carbon steel is quite considerable as the filler rod normally contains very little carbon. Therefore, there is always a tendency of carbon pick particularly when the weldment is cooled rapidly producing a hard and brittle weld deposit. This may also lead to a crack along the line of maximum stress, that is, centre line of the weld.

In medium-carbon steel it is possible to keep the molten metal more fluid at the same temperature than in low carbon steel thus rendering the operator to maintain the welding temperature far above the solidus line to obtain a sufficient fluid puddle for rapid deposition and free evolution of gas.

Sometimes complicated parts, when welded, develop residual stresses due to differential contractions. In such cases it is desirable to have a stress-relieving operation at about 600°C. The duration of the operation will depend on the thickness of the section.

5.6.3 *High Carbon Steel* — High carbon steels contain carbon from 0·6 to 1·2 percent. Welding of high carbon steels by gas welding is a complicated process because the carbon content of the parent metal is very much higher than the carbon content in filler material. There is always a differential cooling rate in molten parent metal and molten filler material leading to crack in the weld junction. Normally a pressure is applied in the weld metal pool during welding which gives a kneeding action leading to a granular refinement in the welding zone. The parent metal is normally preheated to 350°C to avoid cracking and final stress-relieving of the weldment is done at 600°C. The heat treatment at this temperature helps stress-relieving as well as grain refinement. Because of the high temperature of welding the welded zone is always liable to be coarse grained.

5.6.4 *Low Alloy Steels* — Low alloy steels are very large in number and vary in their alloy composition depending upon the properties expected of them. The purpose for which one particular low alloy steel used is quite different from the purpose of other type. The difficulties that are met with in welding of low alloy steels are practically similar to those encountered while welding medium or high carbon steels. The effect of the addition of different alloying elements may be considered as equivalent to increasing the carbon content in so far as its behaviour while cooling from the welding temperature to the room temperature, that is, the susceptibility to cracking in the heat affected zone of the parent metal, under bead cracking and hardening of weld metal due to alloy pick up from the parent metal. One or more of the following precautions as may be necessary, should be taken when welding low alloy steels:

a) Preheating of the parts to decrease the cooling rate after welding to minimize the amount of martensite and prevent the cracking in the heat affected zone;

b) Keeping the weld metal pool to a minimum extent so that the admixture of parent metal and filler metal is kept at a minimum level;

c) All the precautions for the control of distortion should be taken so that weld is subjected to as few stresses as possible during cooling, and

d) A prolonged time of cooling between 400 to 200 C will incidentally help in relieving the residual stresses and in improving the mechanical properties of the weld zone by tempering the martensite formed, if any, during cooling.

5.6.5 *High Alloy Steels* The high alloy steels are also known as special steels. These are normally welded by using the filler rod of same chemical composition. Though a satisfactory weld deposit is never obtained by gas welding of high alloy steels all the special steels are not weldable. The main steels in the weldable group are austenitic manganese steels and stainless steels. Even then gas welding of austenitic manganese steels is not a recommended process. In the case of stainless steels a flux is used to prevent the formation of oxides of the alloying element and the weld metal pool is disturbed by putting the filler rod on the joint instead of the filler rod end in the molten pool.

5.7 Grey Cast Iron — Cast iron is not usually joined by welding except for repair purposes. The carbon content in most cast iron castings ranges from 2·50 to 3·70 percent although a few varieties of high strength, may have little less than 2·5 percent. The silicon percentage varies between 0·50 to 3 0 percent. The filler rod used for cast iron is also cast iron having about 3·0 percent silicon which on melting in the weld metal pool in the presence of flux give an increased fluidity thus preventing the formation of blow holes.

All the cast iron parts to be welded are preheated before welding. The process of preheating is based on the idea of getting softer weld deposit as well as preventing the weld junction crack. The buttering technique is also very much in use in cast iron welding.

In another process known as braze welding a bond is produced by inter-granular penetration of filler metal in the grain boundaries of cast iron. The filler rod used is a copper base alloy. The weld made with braze-welding is just as strong as fusion welding and the weld metal is more ductile. The greatest advantage of braze-welding is that preheating is not very necessary and the preheating temperature does not normally exceed 100°C.

5.8 Malleable Iron — Welding is used to repair the defective malleable iron castings. Fusion welding (like gas welding) is not a suitable process because the molten cast iron on solidification loses the malleable property and transforms into white cast iron. The malleable iron may, however, be braze-welding using similar technique as for grey iron.

5.9 Welding of Non-ferrous Metals and Their Alloys

5.9.1 *Aluminium and Aluminium Alloys* — Aluminium and many of its alloys may be readily welded by gas welding process. Pure aluminium is used where corrosion resistance is prime factor. Aluminium alloys are used where strength is necessary. Pure aluminium is welded with pure aluminium rods in combination with fluxes. Aluminium-silicon alloys are welded with aluminium silicon rods and aluminium magnesium alloys are welded with aluminium alloy rods. A flux is always used while welding aluminium and its alloys.

The surfaces of aluminium to be welded should be free from oil, grease and oxide film. In order to do this the surface is brushed or cleaned chemically. The flux is put on the faces to be welded and the joint is welded with the required type of rod. The melting point of aluminium being low as compared to steels the care that has to be taken by the welder to manipulate molten metal pool is much more than in case of steel. After welding the flux has to be cleaned off thoroughly so that no corrosive action of the flux is present. The cleaning should be done with hot running water until the wash water is free from the chlorides from the flux.

5.9.2 *Copper and Copper Alloys* — Gas welding of copper is comparatively expensive. However, this metal can be advantageously jointed by silver brazing and soft soldering. Copper silicon filler rods may be used in combination with fluxes where the weld metal and parent metal of same composition is not needed.

5.9.2.1 *Welding of bronzes* — Bronze welding is done normally with silicon bronze or phosphor bronze filler rod. A flux to prevent oxidation is always used in welding of bronzes. Moderate peening with a light hammer will increase the mechanical properties of the welded joint.

5.9.2.2 *Welding of brasses* — Brass plates are welded with silicon bronze rods with fluxes and the welding technique is similar to that required for welding of bronze.

5.9.3 *Nickel and Nickel Alloys, and Nicklel Bronze* — The nickel plates are welded with pure nickel rods or nickel bronze rods. The parts need not be preheated in the case of nickel and nickel bronze. Molten nickel being more viscous than steel more manipulation of the weld metal pool is needed while welding nickel and its alloys.

SECTION 6

FILLER RODS AND FLUXES

6.1 General

Selection of the correct filler rod for a particular job is one of the essential prerequisites for successful welding. Cutting out a strip from the material to be welded is not always possible and even when it is possible, such a strip cannot replace a recommended welding filler material. Composition of a filler metal is chosen with special consideration to the metallurgical requirement of a weldment. A wrong choice due to either ignorance or a false consideration of economy may lead to costly failures. IS : 1278-1972* specifies requirements that should be met by filler rods for gas welding. There is another specification IS : 2927-1975† which covers brazing alloys. It is strongly recommended that filler material conforming to these specifications is used. In certain rare cases, it may be necessary to use filler rods of composition not covered by these specifications; in such cases filler rods with well established performance should be used.

Though the inner reducing envelope of an oxy-acetylene flame offers protection to the weld metal, it is necessary to use a flux in most cases. Fluxes used during welding not only protect the weldment from oxidation but also from a slag which floats up and allows clean weld metal, to be deposited. After the completion of welding, flux residues should be cleaned.

6.2 Filler Rods and Fluxes

In Table 1 particulars about the common gas welding rods and brazing alloys with their application and also where the use of flux is necessary is indicated. This table is by no means comprehensive. For more information on the various types of filler rods, reference should be made to the related specification. Fluxes of well established performance should be used.

6.3 Removal of Flux Residues

After welding or brazing is over, it is essential to remove the flux residues. Fluxes in general are chemically active. Therefore, flux residues, if not properly removed, may lead to corrosion of parent metal and weld deposit.

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*Specification for filler rods for gas welding (*second revision*).

†Specification for brazing alloys (*first revision*).

TABLE 1 FILLER METALS AND FLUXES FOR GAS WELDING

(*Clause* 6.2)

FILLER METAL TYPE	APPLICATION	FLUX
Filler Rods Conforming to IS 1278-1972		
Mild steel — Type S FS1	A general purpose rod for welding mild steel where a minimum butt weld tensile strength of 35.0 kg/mm² is required (Full fusion technique with neutral flame)	Not required
Mild steel — Type S FS2	Intended for application in which minimum butt weld tensile strength of 44.0 kg/mm² is required (Full fusion technique with neutral flame)	Not required
Wear resisting alloy steel	Building up worn crossings and other application where the steel surfaces are subject to extreme wear by shock and abrasion (Surface fusion technique with excess acetylene flame)	Not required
3 percent nickel steel — Type S FS4	These rods are intended to be used in repair and reconditioning parts which have to be subsequently hardened and tempered (Full fusion technique with neutral flame)	Special flux (if necessary)
Stainless steel decay resistant (niobium bearing) — Type S Bo2MoNb	These rods are intended for use in the welding of corrosion resisting steels such as those containing 18 percent chromium and 8 percent nickel (Full fusion technique with neutral flame)	Flux required
High silicon cast iron — Type S CI1	Intended for use in the welding of cast iron where an easily machinable deposit is required (Full fusion technique with neutral flame)	Flux necessary
Copper filler rod — Type S C1	For welding of de-oxidized copper (Full fusion technique with neutral flame)	Flux necessary
Brass filler rod — Type S C6	For use in the braze welding of copper and mild steel and for the fusion welding of material of the same or closely similar composition (Oxidizing flame)	Flux necessary
Manganese bronze (high tensile brass) Type S C8	For use in braze welding of copper, cast iron and malleable iron and for the fusion welding of materials of the same or closely similar composition (Oxidizing flame)	Flux necessary
Medium nickel bronze — Type S C9	For use in the braze welding of mild steel cast iron and malleable iron (Oxidizing flame)	Flux required
Aluminium (Pure) — Type S C13	For use in welding of aluminium grade 1B (Full fusion technique with neutral flame)	Flux necessary
Aluminium alloy 5 percent silicon — Type S NG21	For welding of aluminium casting alloys, except those containing magnesium, or zinc as the main addition. They may also be used to weld wrought aluminium magnesium silicon alloys (Full fusion technique with neutral flame)	Flux necessary
Aluminium alloy 10-13 percent silicon Type 5 NG2	For welding high silicon aluminium alloys. Also recommended for brazing aluminium (Neutral flame)	Flux necessary
Aluminium alloy 5 percent copper	For welding aluminium castings particularly those containing about 5 percent copper (Full fusion technique with neutral flame)	Flux necessary

(*Continued*)

TABLE 1 FILLER METALS AND FLUXES FOR GAS WELDING — *Contd*

	Filler Metal Type	Application	Flux
	Stellite Grade 1	Hardfacing of components subjected mainly to abrasion (Surface fusion technique with excess acetylene flame)	None is usually required A cast iron flux may be used, if necessary
	Stellite Grade 6	Hardfacing of components subjected to shock and abrasion (Surface fusion technique with excess acetylene flame)	-do-
	Stellite Grade 12	Hardfacing of components subjected to abrasion and moderate shock (Surface fusion technique with excess acetylene flame)	-do
Brazing Alloys Conforming to IS : 2927 1975	Copper phosphorus brazing alloy — Type BA CuP2	Brazing copper, brass and bronze components (Brazing with slightly oxidizing flame on copper neutral flame on copper alloys)	None for copper For brass or bronze a copper welding flux may be used
	Silver copper phosphorus (14 percent silver) — Type BA CuP5	For making ductile joint in copper without flux Also widely used on copper base alloys of the brass and bronze type in conjunction with a suitable silver brazing flux (Flame slightly oxidizing on copper neutral on copper alloys)	None for copper A flux is necessary for brazing copper alloys
	Silver copper phosphorus (2 percent silver) *type brazing alloys — Type BA-CuP3*	Similar to type BA CuP5 but with a slightly lower tensile strength and electrical conductivity *(Flame slightly oxidizing on copper, neutral on copper alloys)* Note — Phosphorus bearing silver brazing alloys should not be used with ferrous metal or alloys of high nickel content	None for copper A flux is necessary for brazing copper alloys
	Silver-copper zinc (61 percent silver) — Type BA Cu AG6	This brazing alloy is particularly suitable for joining electrical components requiring high electrical conductivity (Flame neutral)	Flux necessary
	Silver copper zinc (43 percent silver) — Type BA Cu Ag16	This is a general purpose brazing alloy and is particularly suitable for food handling and processing equipment where the use of quaternary alloys containing cadmium is objectionable (Flame neutral)	Flux necessary
	Silver-copper zinc cadmium (43 percent silver) — Type BA-Cu Ag16A	An ideal composition for economy in brazing operation requiring a low temperature, quick and complete penetration Suitable on steel, copper, brass, bronze, copper-nickel alloys and nickel silver (Flame neutral)	Flux necessary
	Silver-copper zinc cadmium (50 percent silver) — Type BA-Cu Ag11	This alloy is also suitable for steel, copper, brass, bronze, copper-nickel alloys and nickel-silvers (Flame neutral)	Flux necessary
	Silver-copper-zinc cadmium nickel (50 percent silver) — Type BA Cu-Ag12	Specially suitable for brazing tungsten carbide tips to rock drills, milling cutters, cutting and shaping tools, also suitable for brazing steels which are difficult to 'wet' such as stainless steels (Flame neutral)	Flux necessary

Some hints for removal of flux residues are given below:

a) *Aluminium and Aluminium Alloys* — As soon as possible after welding, wash the joints in warm water and brush vigorously. When conditions allow, follow up by a rapid dip in a 5 percent solution of nitric acid; wash again, using hot water to assist drying.

When containers, such as fuel tanks, have been welded and parts are inaccessible for the hot water scrubbing method, use a solution of nitric and hydrofluoric acids. To each 5·0 litres of water add 400 ml of nitric acid (specific gravity 1·42) followed by 33 ml of hydrofluoric acid (40 percent strength). The solution used at room temperature will generally completely remove the flux residue in 10 minutes, producing a clean uniformly etched surface, free from stains. Following this treatment the parts should be rinsed with cold water and finished with a hot water rinse. The time of immersion in hot water should not exceed three minutes, otherwise staining may result; after this washing with hot water the parts should be dried. It is essential when using this treatment that rubber gloves be worn by the operator and the acid solution should preferably be contained in an aluminium vessel.

b) *Magnesium Alloys* — Wash in water followed quickly by standard chromating. Acid chromate bath is recommended.

c) *Copper and Brass* — Wash in boiling water followed by brushing. Where possible, a 2 percent solution of nitric or sulphuric acid is preferred to help in removing the glassy slag, followed by a hot water wash.

d) *Stainless Steel* — Treat in boiling 5 percent caustic soda solution, followed by washing in hot water. Alternatively, use a de-scaling solution of equal volume of hydrochloric acid and water to which is added 5 percent of the total volume of nitric acid with 0·2 percent of total volume of a suitable restrainer.

e) *Cast Iron*—Residues may be removed easily by a chipping hammer or wire brush.

f) *Silver Brazing* — The flux residue can be easily removed by soaking brazed components in hot water, followed by wire brushing. In difficult cases the work piece should be immersed in 5 to 10 percent sulphuric acid solution for a period of 2 to 5 minutes, followed by hot water rinsing and wire brushing.

SECTION 7

WELDING TECHNIQUE AND PROCEDURE

7.1 General

Oxy-acetylene welding is fundamentally simple. Two pieces of metal are brought together and the edges in contact are melted by the oxy-acetylene flame with or without the addition of molten metal from a welding rod. Welds made in this manner are known as ' fusion welds '. In braze welding and brazing, base metal is not fused with weld metal but a joint is produced through the formation of a strong bond between the weld metal and the base metal. Rules for practical applications, of course, cannot be stated so easily but the art of oxy-acetylene welding nevertheless retains this essential simplicity.

7.2 The Oxy-Acetylene Flame

The oxy-acetylene flame is an ideal source of heat for welding. It produces a high temperature flame and the region of high temperature is restricted to a small area. The inner mantle of the flame reaches a temperature of about 3 200 C and is surrounded by a reducing atmosphere composed mainly of carbon monoxide and hydrogen. This reducing envelope protects the molten metal from oxidation during welding. Final combustion of carbon monoxide and hydrogen of the inner envelope takes place in the outer zone of the flame producing water vapour and carbon dioxide. For complete combustion, one volume of acetylene requires two and a half volumes of oxygen, of which approximately one volume is supplied from the cylinder and one and a half volume from the surrounding atmosphere.

The technique of flame adjustment has been explained in Section 3. Three types of flames, namely: (a) the neutral flame, (b) the oxidizing flame, and (c) the carburizing flame, depending on the gas mixture, are shown in Fig. 7.1 and 7.2.

With the complete combustion of acetylene, one gets a neutral flame, with a clearly defined white cone. It is, however, not desirable to have a sharp line at the tip of the white cone, the correct adjustment should produce a faint ' haze ' or ' flicker ' around the end. It should be mentioned here that the hottest temperature in the flame is obtained at a point just in front of the inner white cone. The neutral flame is used to weld steel, stainless steel, cast iron, aluminium, etc

In an oxidizing flame there is an excess of oxygen. The white cone becomes shorter, pointer and a little bluish. For producing an oxidizing flame, a neutral flame is produced first and then acetylene flow is slightly decreased to give an oxidizing flame. The oxidizing flame is used to weld brasses and in bronze welding.

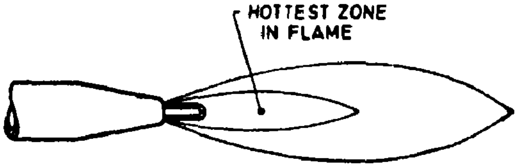
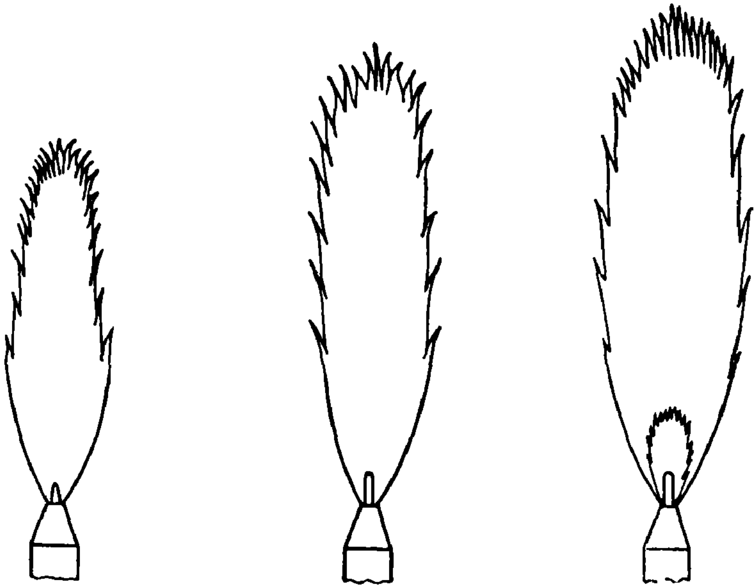


FIG. 7.1 SECTION OF OXY-ACETYLENE FLAME



7.2A Oxidizing Flame (Excess of Oxygen) (An oxidizing flame is necessary for welding brass)

7.2B Neutral Flame (Equal Quantities of Oxygen and Acetylene) (For steel, stainless steel, cast iron, copper, aluminium, etc)

7.2C Carburizing Flame (Excess of Acetylene) (A small excess of acetylene is necessary for stelliting, hardfacing, etc)

FIG. 7.2 OXIDIZING, NEUTRAL AND CARBURIZING FLAME

Carburizing or reducing flame is the one in which there is an excess of acetylene. Excess acetylene feather is distinctly visible and a reducing flame can be easily distinguished from a neutral flame. Here again a neutral flame should be produced first and then acetylene flow increased to get the required carburizing flame. The carburizing flame is generally used for depositing special surfacing metals like stellite and wear-resisting steels.

NOTE — In order to get the required flame it is essential that the welding nozzle should be kept clean by probing the orifice with a copper wire. But no sharp instrument, such as a drill or reamer should be used for this purpose.

7.3 Preparation for Welding

7.3.1 *Type of Joints* — Joint edges are generally required to be prepared prior to welding. It is possible to make a plain butt joint in thin sheet metal provided the edges are square (true) and clean, but thicker plates have to be dressed to a ' Vee ' preparation to allow the flame to penetrate the full depth of the plate. The shape of the ' Vee ' depends on the weld technique adopted and this will be discussed later. Figure 7.3 illustrates various butt and fillet welds.

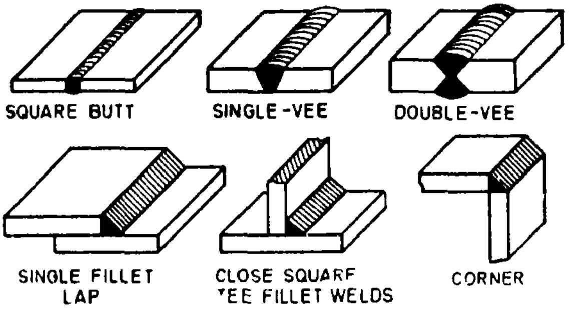


FIG. 7.3 BUTT AND FILLET WELDS

The correct preparation of edges is essential in the production of sound welds.

The edge preparation, welding technique and speed for various thicknesses of mild steel using down-hand position of welding are illustrated in Fig. 7.4.

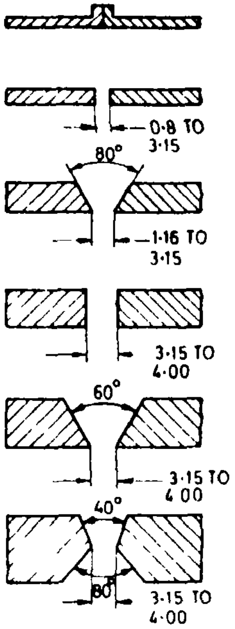
7.3.2 *Tacking* — The effect of expansion while butt welding two sheets of metals without any precautions can be seen in Fig. 7.5.

The edges here were originally in contact along the whole length of the joint. When the weld is started, the edges first recede and then close up until finally towards the end of the weld they overlap. The weld cannot, therefore, be completed. To overcome this, the sheets can be tack-welded at regular intervals along the line of the weld with tacks about 25 mm.

On thicker plate, the method usually adopted is to arrange the two plates so that they diverge from the point where welding commenced. This spacing may be maintained by the use of clamps and is particularly applicable to the longitudinal seams in cylinders (*see* Fig. 7.6).

The divergence allowance varies very slightly with the thickness and the speed of welding, but may be assessed as follows:

Steel	2 to 3 cm/m
Brass and bronze	1·5 cm/m
Monel	3 cm/m
Aluminium	1·7 cm/m
Copper	1·5 cm/m



All dimensions in millimetres.

Fig. 7.4 Down-Hand Butt Welds in Steel-Edge Preparation and Welding Technique

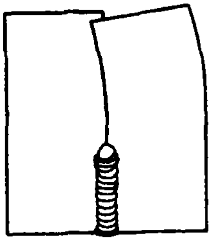


Fig. 7.5 Distortion due to Expansion in Butt Welds Produced Without Tack Welding

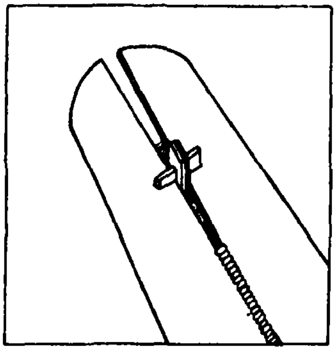


Fig. 7.6 Divergence Allowance to Avoid Distortion

If this method is not applicable, welding should start at the centre of the seam for a short distance, and then a second start should be made at the centre, welding in the opposite direction for a short distance. This method should be continued until the whole weld is completed.

7.4 Welding Jigs and Fixtures

Use of jigs will be found helpful in welding of sheet metal. The jig or fixture should be designed to clamp the parts firmly to avoid movement during welding and subsequent distortion. They can also be arranged to conduct much of the heat away from the weld.

7.5 Welding Techniques

7.5.1 *Leftward or Forward Welding* — Leftward welding technique is used on steel for flanged edge welds, for unbevelled steel plates up to 3·15 mm and for bevelled plates up to 5 mm. It is also the method used for welding of cast iron and non-ferrous metals. The weld is commenced on the righthand of the joint and welding proceeds towards the left. Blowpipe is given a forward motion with a slight side movement just sufficient to maintain both edges melting at a desired rate, and the welding rod is moved progressively along the weld seam (*see* Fig. 7.7).

7.5.2 *Rightward and All-Position Rightward Welding* - Rightward welding is recommended for steel plates above 5 mm in thickness. Plates up to 8 mm in thickness need no edge preparation. Plates above 8 mm in thickness should be bevelled to about 30° to give an included angle of 60° for the ‘ Vee ’ joint.

The weld is commenced at the lefthand end of the joint and the blowpipe moved towards the right. The welding rod is given a circular forward action and the blowpipe moved steadily along the weld seam. Rightward technique is quicker than the leftward method and consumes less gas. Because the included angle is smaller, less welding rod is required. Distortion is also less. The technique is illustrated in Fig. 7.8.

The all-position rightward technique is a modification of the rightward technique whereby the flame precedes the rod. This method is particularly suitable for welding of mild steel plate and pipe in the vertical, horizontal-vertical and overhead positions. The all-position rightward method of welding is illustrated in Fig. 7.9.

It should be stressed that considerable practice is required even by operators skilled in normal downward rightward welding to become familiarized with this technique.

7.5.3 *Vertical Welding* — Vertical welding may be used on unbevelled steel up to 3·15 mm in thickness, and up to 16 mm where two operators are

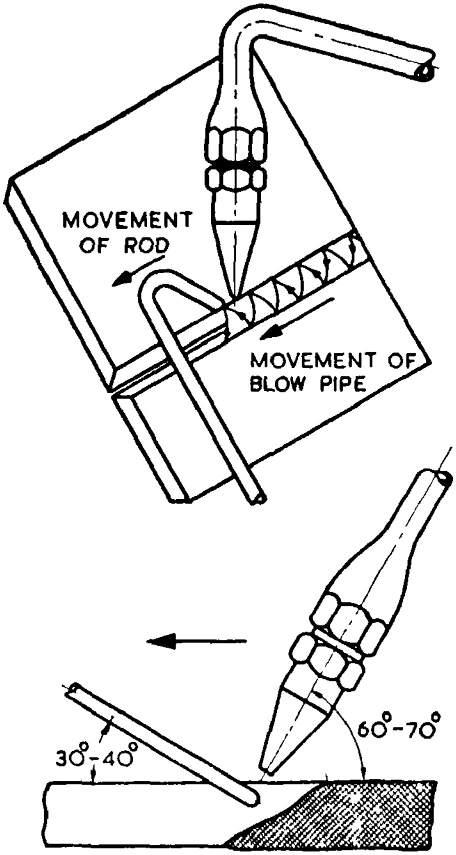


Fig. 7.7 Leftward or Forward Welding Technique

employed. The weld is commenced at the bottom and proceeds vertically to the end of the seam. The blowpipe and the welding rod are given an upward semi-circular motion. For plates 5 to 16 mm in thickness this method requires two operators working opposite to each other — one on each side of the plate (*see* Fig. 7.10 and 7.11).

7.6 Braze Welding

7.6.1 In brazing and braze welding, unlike the fusion welding, parts being united are not normally brought to a temperature which approaches their melting point and in a majority of cases there is no necessary similarity of chemical composition between the filler metals and the parent metals.

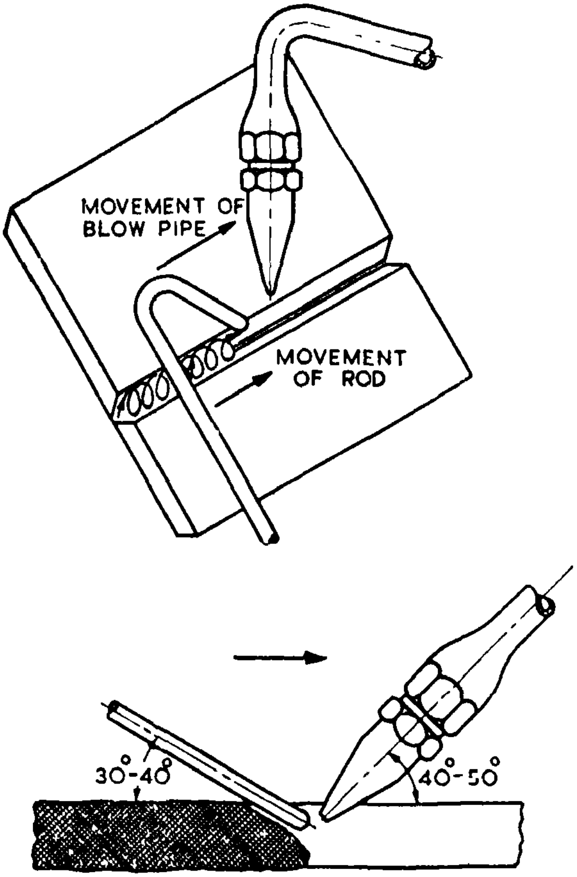


FIG. 7.8 RIGHTWARD TECHNIQUE OF WELDING

7.6.2 Braze welding involves the use of rods which are composed mainly of 60/40 brass with the addition of silicon and tin to act as deoxidizers, and other metals to enhance the mechanical properties. Though metallurgically the rods are brass, by usage these are known as bronze rods such as silicon bronze or nickel bronze rods.

The process takes advantage of the fact that brass filler rods will make a sound bond on copper, steel, cast iron, etc, at temperatures from 800 to 900°C. Very high tensile joints are produced on a very wide variety of metals with minimum amount of heat.

The joint should be clean and free from sharp edges or corners which may result in overheating. Full advantage should be taken in braze welding

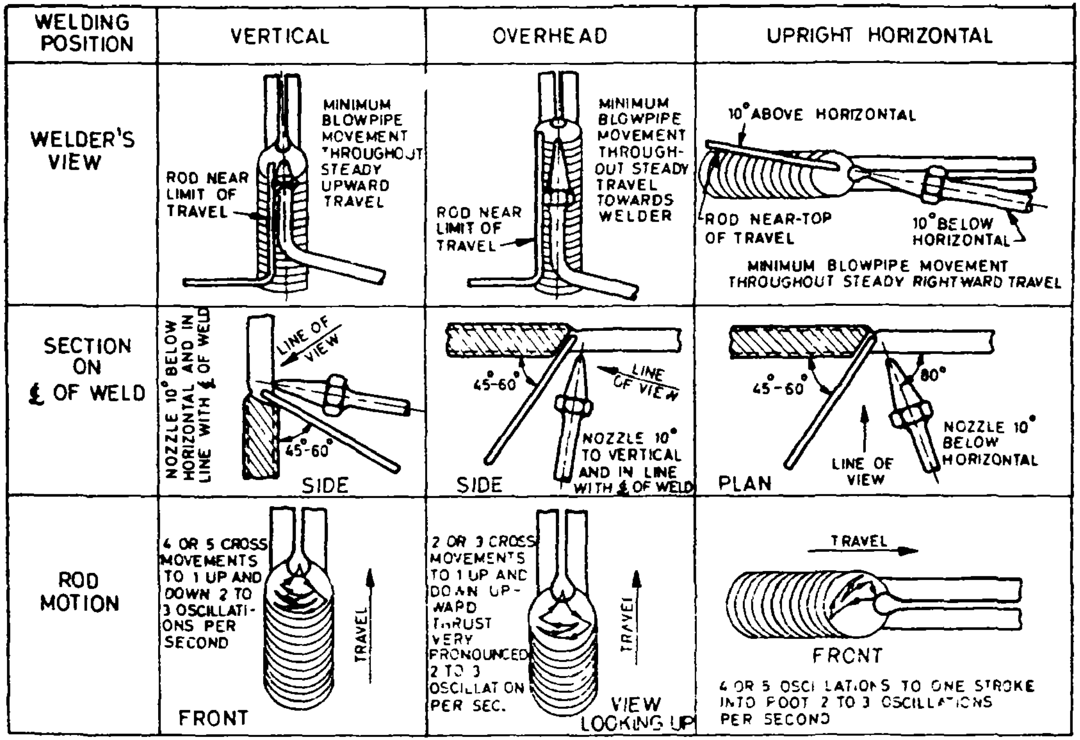
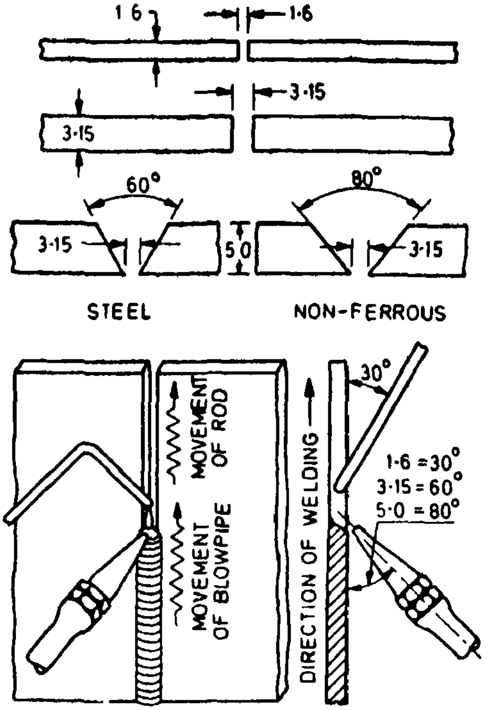

WELDING POSITION
VERTICAL
OVERHEAD
UPRIGHT HORIZONTAL
WELDER'S VIEW
ROD NEAR LIMIT OF TRAVEL
MINIMUM BLOWPIPE MOVEMENT THROUGHOUT STEADY UPWARD TRAVEL
ROD NEAR LIMIT OF TRAVEL
MINIMUM BLOWPIPE MOVEMENT THROUGHOUT STEADY TRAVEL TOWARDS WELDER
10° ABOVE HORIZONTAL
ROD NEAR-TOP OF TRAVEL
10° BELOW HORIZONTAL
MINIMUM BLOWPIPE MOVEMENT THROUGHOUT STEADY RIGHTWARD TRAVEL
SECTION ON ℄ OF WELD
NOZZLE 10° BELOW HORIZONTAL AND IN LINE WITH ℄ OF WELD
LINE OF VIEW
45-60°
SIDE
45-60°
LINE OF VIEW
NOZZLE 10° TO VERTICAL AND IN LINE WITH ℄ OF WELD
SIDE
45-60°
80°
NOZZLE 10° BELOW HORIZONTAL
LINE OF VIEW
PLAN
ROD MOTION
4 OR 5 CROSS MOVEMENTS TO 1 UP AND DOWN 2 TO 3 OSCILLATIONS PER SECOND
TRAVEL
FRONT
2 OR 3 CROSS MOVEMENTS TO 1 UP AND DOWN UPWARD THRUST VERY PRONOUNCED 2 TO 3 OSCILLATION PER SEC.
TRAVEL
VIEW LOOKING UP
TRAVEL
FRONT
4 OR 5 OSCILLATIONS TO ONE STROKE INTO FOOT 2 TO 3 OSCILLATIONS PER SECOND

Fig. 7.9 All-Position Rightward Method of Welding



All dimensions in millimetres.

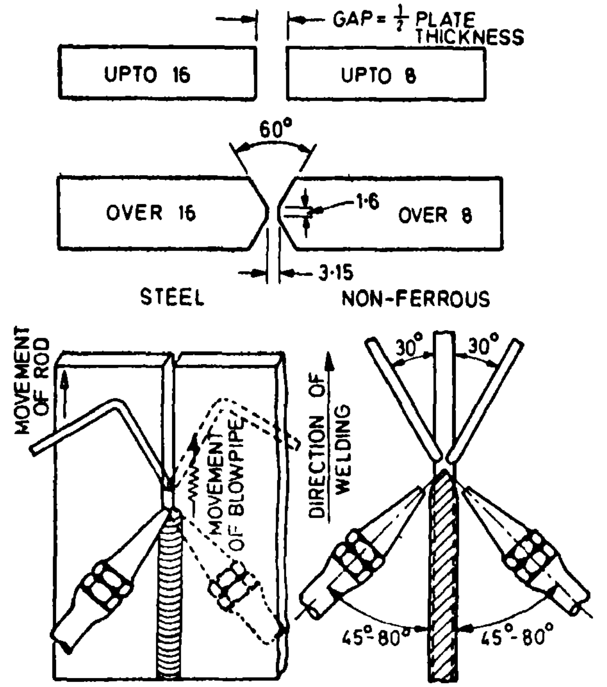
NOTE — No movement of blowpipe on plate up to 3·15 mm thickness. Slight movement of blowpipe as above on plate thicker than 3·15 mm.

FIG. 7.10 VERTICAL WELDING WITH SINGLE OPERATOR

of the high shear strength due to bond between the bronze and the parent metal. Where bevelling is not possible, the width of the bronze deposit at the top should be at least twice the thickness of the parent metal. A special type of joint preparation called ' shear vee-preparation ' which has been devised for high duty work on cast iron is shown in Fig. 7.12.

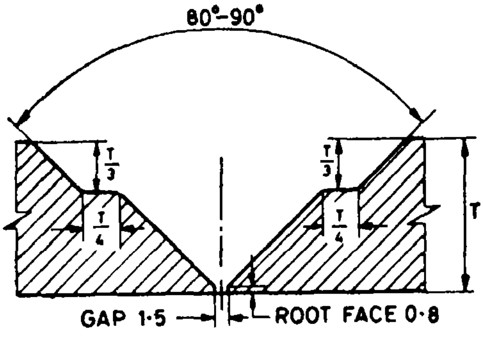
7.6.3 In braze welding a slightly oxidizing flame is employed and the use of a suitable flux is essential. Heat should be kept as localized as possible by the use of a flame of correct size and by working as quickly as possible. The operator should watch to see that the bronze is actually flowing over and ' tinning ' the surface of the metal immediately in front of the flame.

The process enables a weld to be produced without raising the temperature of the parent metal to its fusion point. Dissimilar metals can also be joined with the obvious limitation that neither of the parent metals must



All dimensions in millimetres.

Fig. 7.11 Vertical Welding with Two Operators



NOTE—ALL EDGES RADIUSED

All dimensions in millimetres.

Fig. 7.12 Shear Vee-Preparation for Braze Welding of Cast Iron

fuse at a lower temperature than the filler metal and further, they must be of such a nature that amalgamation can take place between them and the filler metal.

Braze welding should not be employed:

a) when the service temperature goes beyond 250°C,

b) where there is a change of electrolytic action, and

c) when there is an objection to colour dissimilarity.

7.6.4 In the case of cast iron, braze welding is used chiefly for the repair of broken castings, and for the rebuilding of such parts as broken gear teeth. (Reference may be made to IS : 5139-1969* for further details.) Welding proceeds by the leftward or upward vertical method according to the position of the joint, the welding blowpipe being given a steady semicircular movement. The rod is applied to the edges of the metal with a rubbing action as soon as bronze is seen to run forward and 'tin' the heated surface. Braze welding is applicable to malleable iron castings also Figures 7.13 and 7.14 show the preparation and technique of braze welding of cast iron.

7.6.5 Braze welding is also applicable to steel and very often used where it is necessary to avoid putting more than the minimum amount of heat into the work. Braze welding is also used on galvanized iron. Before commencing the weld, the upper and lower edges should be smeared with a copper welding flux to protect the zinc coating.

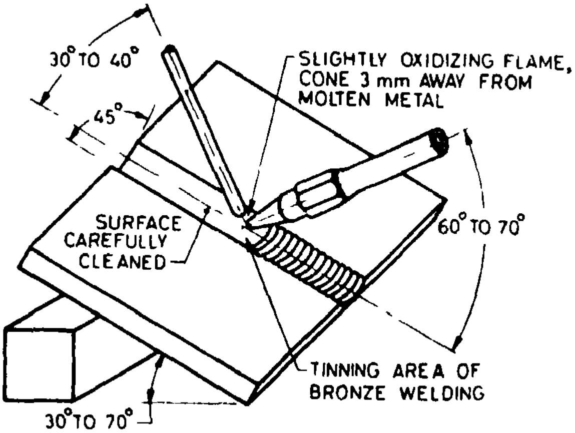

30° TO 40°
45°
SLIGHTLY OXIDIZING FLAME, CONE 3 mm AWAY FROM MOLTEN METAL
SURFACE CAREFULLY CLEANED
60° TO 70°
TINNING AREA OF BRONZE WELDING
30° TO 70°

FIG. 7.13 ANGLES OF ROD AND BLOWPIPE FOR BRAZE-WELDING OF CAST IRON

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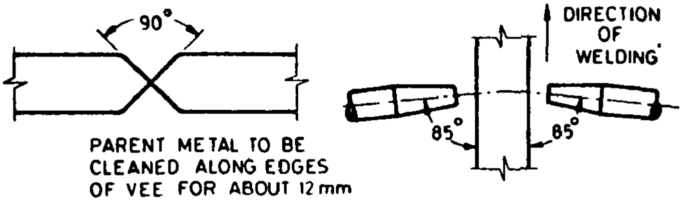
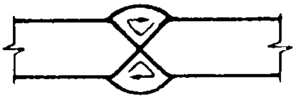
*Recommended procedure for repair of grey iron castings by oxy-acetylene and manual metal arc welding.


90°
PARENT METAL TO BE CLEANED ALONG EDGES OF VEE FOR ABOUT 12 mm
DIRECTION OF WELDING
85°
85°

PREPARATION OF PLATE EDGES

ANGLE OF BLOWPIPES



BLOWPIPE AND ROD MOVEMENT

FIG. 7.14 PREPARATION AND TECHNIQUE FOR TWO-OPERATOR VERTICAL BRAZE-WELDING OF CAST IRON

7.6.6 By the use of braze welding it is possible to carry out successful welds on deoxidized as well as non-deoxidized copper. Figure 7.15 shows some of the braze welded copper pipe joints.

7.7 Brazing

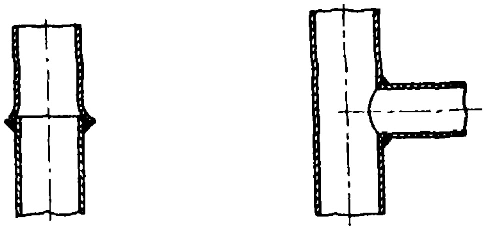
7.7.1 It will be seen that in braze welding the joint gap is filled by a filler metal just as in fusion welding; and Vee preparations are very often made. Brazing is a non-fusion process and is different from braze welding in that a joint is made by causing the molten filler metal to be drawn by capillary attraction into the space between closely adjacent surfaces of the parts to be joined. It is the use of the phenomenon of capillary attraction which differentiates the process of brazing from braze welding. To avoid confusion with soft soldering which also employs the phenomenon of capillary attraction, it is presupposed that for brazing the melting point of the filler metal is above 500°C. Given below are the terms which are commonly used to indicate the brazing process:

a) *Brazing* — Soldering with brass in strict sense, but commonly applied much more generally.

b) *Silver brazing, silver soldering or low temperature brazing* — These terms are used to define brazing in the temperature range of 600°C to 850°C using filler metals based mostly on the metals silver and copper.

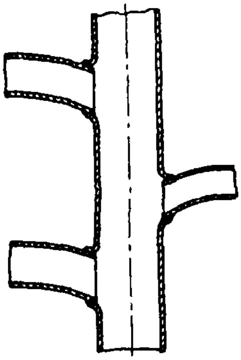
c) *Aluminium brazing* — Brazing aluminium and certain aluminium alloys using aluminium silicon alloys.

d) *Copper brazing* — The term is generally applied to the brazing of various metals with copper in reducing atmosphere furnaces.



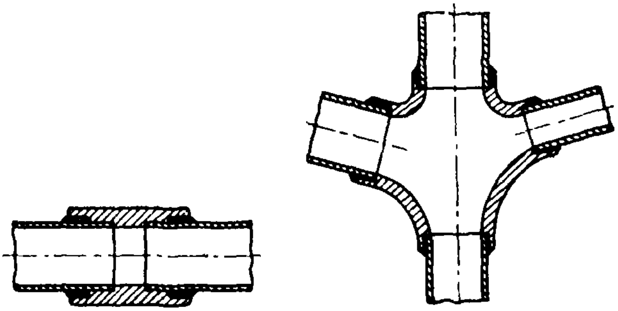
A Bell type butt joint

B Branch tee saddle joint



C Bell type tee joint

D Diminishing joint



E Straight weldable copper socket

F Four-way unequal branch weldable copper fitting

FIG. 7.15 BRAZE WELDED COPPER PIPE JOINTS

A comparison of joints used in welding and brazing is shown in Fig. 7.16.

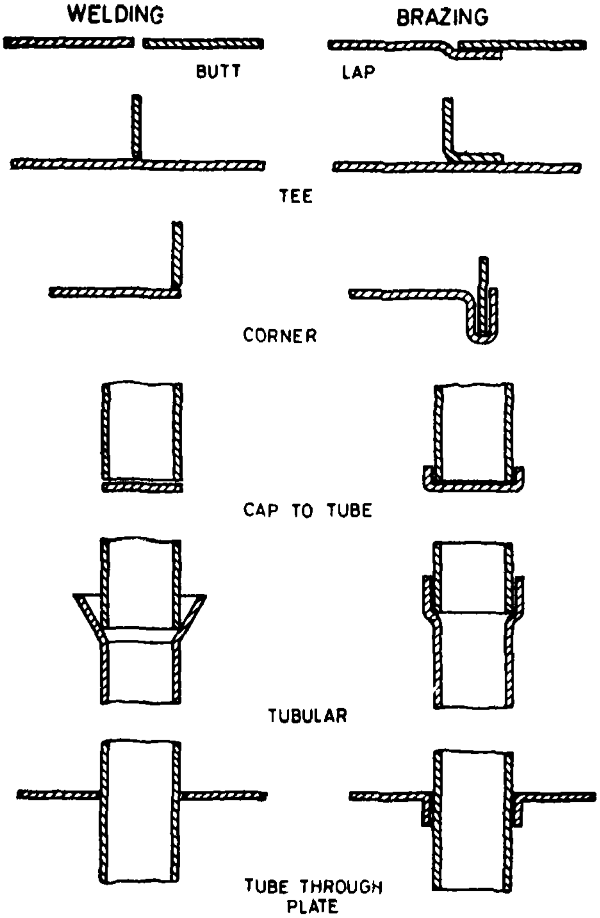


FIG. 7.16 WELDED AND BRAZED JOINTS

7.8 Hard Facing

7.8.1 Hard facing is the technique of depositing by welding a wear-resisting alloy on a metal surface subject to wear resulting from impact, abrasion, erosion or corrosion or combination of these.

In general hard facing deposit is applied on a steel base using a reducing flame. If the base is clean a flux is seldom necessary. To cite a typical application, a low melting point high carbon alloy such as high chromium iron or a Cr-Co-W alloy is deposited on low or medium carbon steels. The blowpipe is adjusted to have an excess of acetylene giving a feather of about 1½ to 2½ times the length of the neutral inner cone. The reducing flame carburizes the surface, thus lowering its melting point and finally melts a film on the surface. The melting of the surface film gives the appearance of 'sweating'. The tip of the hard surfacing rod preheated on the fringe of flame is now moved into the heat centre of the flame and melted down on the 'sweated' metal surface (*see* Fig. 7.17). On completion of the deposit, the work must be allowed to cool down slowly either in a furnace or in lime or mica dust.

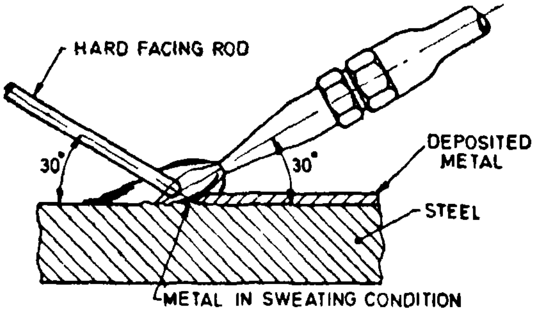


FIG. 7.17 HARD FACING ON STEEL SURFACE

It should be mentioned that not all alloys require a reducing flame. Therefore, manufacturer's recommendation should be followed in using any hard facing rod.

7.9 Gas Welding of Various Metals

7.9.1 *Mild Steel* — Little difficulty is experienced in the welding of mild steel. Various techniques of welding applicable to mild steel and the preparation for welding have already been discussed. Mild steel filler rod of proper composition (*see* Section 6) should be used. The blowpipe flame should be adjusted to neutral.

Welding speeds and data for welding of mild steel are given in Tables 7.1, 7.2 and 7.3.

7.9.2 *Stainless Steel* — An austenitic stainless steel on welding may lose its corrosion-resisting properties. This will happen when the stainless steel used is not stabilized. Stainless steels depend for their stainless properties on the presence of chromium. On welding an unstabilized stainless steel, chromium in the heat-affected zone is precipitated along the grain boundaries as chromium-carbides and this results in the loss of stainless properties in that zone. This phenomenon is known as 'weld decay'. This can

TABLE 7.1 WELDING SPEEDS AND DATA FOR LEFTWARD WELDING OF STEEL

(*Clause* 7.9.1)

THICKNESS OF PLATE	FLOW RATE OF EACH GAS (OXYGEN AND ACETYLENE)	DIAMETER OF FILLER WIRE	RATE OF WELDING	ROOT-GAP	WELDING ROD USED PER METRE OF WELD	PREPARATION OF EDGES
(1)	(2)	(3)	(4)	(5)	(6)	(7)
mm	l/h	mm	m/h	mm	mm	
0·8	30- 60	0·8	6 -7·5	—	1 000	Square edges
1·6	60- 90	1·6	7·5-9·0	—	1 750	
2·5	90-150	1·6 or 2·5	6·0-7·5	1·5	2 750	
3·15	150-210	2·5	5·5-7·5	1·5	1 650	
4·0	210-300	3·15	4·5-5·5	1·5	2 100	'Vee' weld with included angle between 80°-90°
5·0	300-370	3·15	3·7-4·5	2·5	4 800	

NOTE — The values given in this table are only indicative.

TABLE 7.2 WELDING SPEEDS AND DATA FOR RIGHTWARD WELDING OF STEEL

(*Clause* 7.9.1)

THICKNESS OF PLATE	FLOW-RATE OF EACH GAS (OXYGEN AND ACETYLENE)	DIAMETER OF FILLER WIRE	RATE OF WELDING	ROOT-GAP	WELDING ROD USED PER METRE OF WELD	PREPARATION OF EDGES
(1)	(2)	(3)	(4)	(5)	(6)	(7)
mm	l/h	mm	m/h	mm	mm	
5·0	370- 510	2·5	3·7-4·5	2·5	3 400	Square edge
6·3	510- 710	3·15	3·0-3·7	3·0	3 400	
8·0	710- 850	4·0	2·2-2·4	4	3 400	'Vee' weld with included angle 60°
10·0	990-1 300	5·0	1·8-2·1	3	5 250	
12	1 300-1 420	6·3	1·3-1·5	3	4 750	
16	1 550-1 700	6·3	1·1-1·3	3	6 750	
20	1 700-2 000	6·3	0·9-1·0	3	9 750	
25	2 000-2 600	6·3	0·6-0·7	3	16 500	

NOTE — The values given in this table are only indicative.

TABLE 7.3 WELDING SPEEDS AND DATA FOR VERTICAL WELDING STEEL

(*Clause* 7.9.1)

Thickness of Plate	Flow-Rate of Each Gas per Blowpipe	Diameter of Filler Wire	Rate of Welding	Root-Gap	Welding Rod Used per Metre of Weld	No. of Operations	Preparation of Edges
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
mm	l/h	mm	m/h	mm	mm		
1·6	75- 90	1·6	4·5	—	2 500	1	Square edge
2·0	90-105	1·6	3·7	0·8	2 750	1	
3·15	150-165	2·0	3·0	0·8	3 200	1	
4	180-210	2·0	2·4	1·0	4 000	1	
5	225-255	2·5	2·1	1·5	3 750	1	
5	60- 90	1·6	3·7	2·5	7 500	2	
6·3	90-120	2·5	3·0	3·0	6 200	2	
8	150	3·15	2·6	4·0	5 300	2	
10	210	4·0	2·3	5·0	4 900	2	
12	300	4·0	1·8	6·0	7 250	2	

Note 1 — The double operator technique is effective from 5 mm thickness upwards.

Note 2 — The values given in this table are only indicative

be obviated by suitable heat treatment which involves raising the temperature to 1 050°C, followed by rapid cooling. As this may not always be a practicable proposition, it is desirable to use a stabilized stainless steel or extra low carbon stainless steel filler rod. Stainless steel is stabilized with the addition of either titanium or columbium. As these elements have more affinity for carbon compared to chromium, titanium or columbium carbides are formed in preference to chromium carbides, thus avoiding weld decay. In extra low carbon stainless steel, carbon percentage is kept very low, so that there is insufficient carbon available for the formation of chromium carbides.

Stainless steel filler rods stabilized with columbium are generally used for welding. A flux is recommended, and when preparing for the weld, it should be mixed to a paste and painted on the underside of the sheet. The welding rod should also be fluxed by heating and dipping in the flux. Compared with mild steel, the coefficient of expansion of stainless steel is 50 percent greater and its heat conductivity is half. It is, therefore, desirable to use a nozzle one or two sizes smaller than required for an equivalent thickness of mild steel, and a flame that is neutral but not oxidizing. Work once started, should be finished without interruption and the rod should always be kept under the protection of the flame envelope.

7.9.3 *Cast Iron* — Welding of cast iron needs careful thought and preparation. Cast iron, like all other cast metals, will tend to develop cracks on welding because of its low ductility. It is therefore desirable to preheat cast iron. Preheating temperature for fusion welding is about 700°C (dull red). Braze welding of cast iron is done at lower temperature and consequently the preheating temperature is also less, say, about 400°C (black heat).

The variety of cast iron that a welder normally is required to repair is grey cast iron. Cast iron contains about 3 to 4 percent carbon. In grey cast iron, most of this carbon is present as free carbon in the form of flakes of graphite, which when evenly distributed give the characteristic grey colour. This form of cast iron is the most common, and the metal has good mechanical properties and is easy to machine.

In welding, it should be the aim of the welder to deposit grey cast iron. In molten condition, most of the carbon is in the form of iron-carbide. Slow cooling from the molten condition separates carbon in the form of graphites. Silicon in cast iron also helps in this separation and in the random distribution of graphites. Cast iron welding rods should, therefore, contain sufficient quantity of silicon. If the molten cast iron is quickly cooled, the separation of iron carbide to iron and carbon cannot take place and the deposit becomes white cast iron which is difficult to machine and is extremely brittle. It is, therefore, essential that the weld depsoit is slowly cooled. Use of flux is essential to prevent oxidation.

In fusion welding cast iron, the flame should be neutral, and applied at an angle of 60° to 70° to the surface. The weld should consist of a series of overlapping pools, and the rod should be allowed to fall naturally into the weld without ' puddling '. Cracks in cast iron should be prepared to 90° Vee. Above 12 mm thickness, double ' Vee ' preparation is desirable. Preheating of castings will be discussed in more detail in **7.10.2**.

7.9.4 *Malleable Iron* — Malleable iron is cast iron with a ductile skin as its outer layer. This ductile layer confers malleable property to the malleable iron. Welding causes the loss of this malleable property. Malleable iron, therefore, should not be repaired by fusion welding. Braze welding is recommended.

7.9.5 *Aluminium* — The properties of aluminium which have most effect on its welding characteristics are its low melting point (659°C), its high thermal conductivity, its affinity for oxygen especially when heated, and its being structurally weak when hot.

Pure aluminium welding rods should be used for welding pure aluminium plates or sheets but for welding most of the aluminium alloy, a 5-percent silicon aluminium rod is found useful. A filler rod for an alloy is naturally dictated by its composition.

Because of its affinity for oxygen, an oxidizing flame should never be used with aluminium. A neutral flame is used but to be sure that it is not oxidizing a slight haze of acetylene should be maintained.

A highly active flux is necessary to deal with the refractory oxides of aluminium. It is essential to remove the flux residues after welding by washing in hot water along with wire-brushing.

Joints such as laps and fillets which have got chances of entrapping the flux, shall not be employed in oxy-acetylene fusion welding of aluminium. Some joints used in aluminium welding are illustrated in Fig. 7.18. Such joints in pure aluminium can however be brazed using 10 to 12 percent silicon aluminium rod and a suitable flux. The brazing material flows inside due to capillary action and drives out the corrosive flux.

Leftward or upward vertical methods may be used in aluminium welding as shown in Fig. 7.19 and 7.20.

7.9.6 *Cast Aluminium* — Aluminium castings usually contain proportions of other metals and the welding rod should be of suitable composition. A 5-percent silicon aluminium rod will be found useful in most cases. Use of flux is essential. The flux residues shall be removed after welding.

Details regarding welding of castings are discussed in **7.10**.

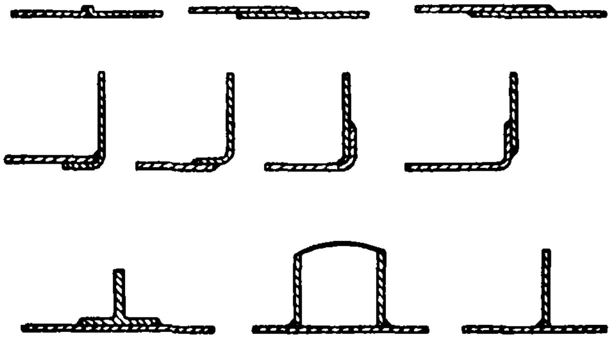


FIG. 7.18 TYPICAL JOINTS IN ALUMINIUM WELDING

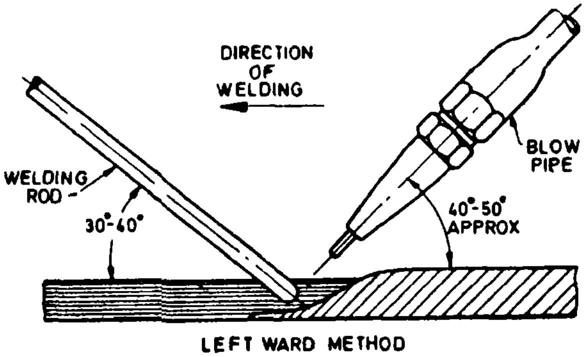


FIG. 7.19 LEFTWARD METHOD OF GAS WELDING ALUMINIUM

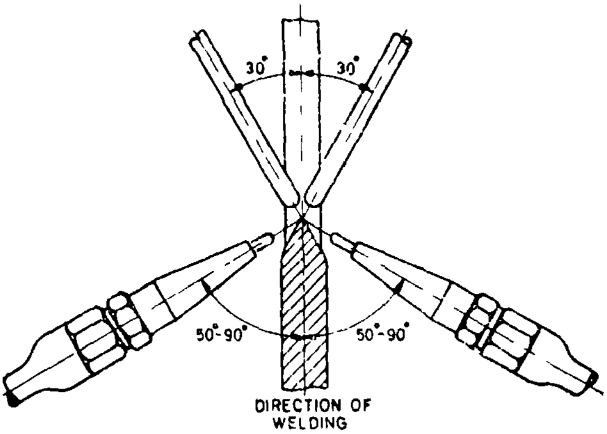


FIG. 7.20 UPWARD VERTICAL METHOD OF GAS WELDING ALUMINIUM

7.9.7 *Duralumin and Alclad* — Duralumin is an aluminium alloy having exceptional mechanical properties When duralumin is coated with pure aluminium, the product is known as 'Alclad' Gas welding of these two materials is not recommended Where strength is of no importance, welding may be carried out using 5-percent silicon aluminium rod.

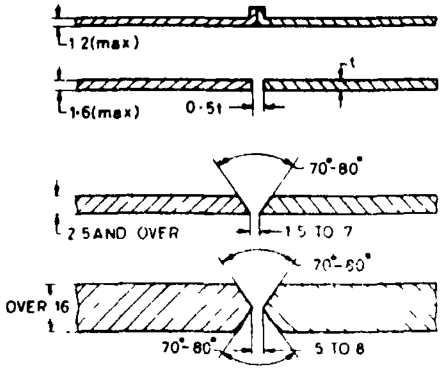
7.9.8 *Copper* — For fusion welding, the copper should be of 'deoxidized' variety. The grades of copper containing oxygen are not suitable for fusion welding owing to the formation of cuprous oxide — a copper eutectic — which leads to porosity and cracking of the weld metal. Such copper should be braze welded

To produce fusion welding a suitable welding rod containing deoxidants should be used Use of a flux should be found beneficial. Because of high thermal conductivity, copper requires a larger nozzle than required for steel and it is advisable to employ a second blowpipe ahead of the weld to preheat the metal. Butt welds in plates should be set with a gap which diverges by about 1·5 cm per metre. A backing strip covered with dry asbestos will provide a support and concentrate the heat.

Copper should not be tack-welded and to avoid cracking due to hot-shortness long seams can be started 100 to 150 mm from one end, carrying the weld to the other end in one operation, and then returning to the starting point to complete the weld seam Welds in thin plate should be completed in one run, although this will not be possible for thicker plate. In the latter case step welding is possible, provided the bottom run is laid down for lengths not exceeding about 100 mm at a time. Where possible the vertical upward method is to be preferred, and plates over 3 mm thick can be welded by this procedure. Light hammering at temperatures above 600°C helps to break up the eutectic and prevents excessive grain growth, while cold-hammering improves the mechanical properties.

The flame should be neutral and to ensure this, it should be adjusted to a slight excess of acetylene feather.

Edge preparations for copper welding are shown in Fig. 7.21.



All dimensions in millimetres.

FIG. 7.21 EDGE PREPARATION FOR COPPER WELDING (DOWNHAND WELDING)

7.9.9 *Brass* — Alloys of copper and zinc in various proportions, possibly with the addition of other elements, are known as brasses. Copper melts at 1 083°C and zinc melts at 419°C, and brasses melt at intermediate temperatures. The low melting point of zinc and its tendency to volatalize at welding temperatures, have to be considered in selecting the correct flux and flame for welding brasses.

Loss of zinc can be controlled by using an oxidizing flame, and it is better to set the flame first to neutral and then gradually reduce the acetylene flow, testing a peice of scrap brass with the flame until the fuming ceases. The metal should be properly fluxed and if a test by welding shows that blow holes are being produced, acetylene flow should be decreased still further. In order to obtain a soft flame, it is desirable to choose a nozzle one size larger than would be used for welding steel.

A welding rod to suit the composition should be chosen and welding carried out with an appropriate flux. Material 3 mm thick and over should be bevelled to an included angle of 90°C. The joint should be thoroughly cleaned, and fluxed, on both sides prior to welding.

7.9.10 *Bronze* — Alloys of copper and tin, in proportions ranging from 80 to 90 percent of copper, sometimes with the additions of lead and other metals, are known as bronzes. High lead-tin alloys are termed gun metal, and phosphor bronze contain a proportion of phosphorous in addition. When heated, the metal appears to boil, and loss of tin and lead can only be prevented by an abundant use of flux. A neutral flame is normally required, and the tip of the inner cone should be held 40 to 50 mm clear of the weld, to reduce loss of tin. The welding procedure generally recommended for brass will give satisfactory results.

Castings benefit from preheating and it is necessary to support the metal in the vicinity of the weld.

7.9.11 *Monel Metal and Nickel* — Monel contains approximately 67 percent nickel and 30 percent copper together with iron, manganese, silicon, etc, and is used in the dairy and food industries.

Sheets up to 1·2 mm thick should be flanged and thicker sheets prepared with 90° ' Vee '. Suitable rod and flux should be used and the flame should be slightly reducing. Nozzle one size larger than that used for steel is required.

Pure nickel can be welded in a similar manner using nickel welding rod and both the material can be soft and hard soldered. Both leftward and rightward technique can be employed but the latter is found to be advantageous.

7.9.12 *Inconel* — An alloy of nickel, chromium and iron, inconel is used where corrosion and heat resistance are required. It can be welded with a slight excess acetylene flame, in conjunction with a suitable welding rod and flux pasted on the surface to be joined as well as on the welding rod.

7.9.13 *Everdur* — An alloy of 96 percent copper with 5 percent silicon and 1 percent manganese, everdur is used in hot water service, especially in the presence of corrosive substances. With a slightly oxidizing flame and wire or strip cut from the everdur metal itself, welding can be successfully carried out. A copper welding flux should be used. The low thermal conductivity of the metal enables a smaller size nozzle to be used than for copper of same thickness.

7.9.14 *Magnesium Alloys* — Becuase of their being light, magnesium alloys are being used in increasing quantities. A neutral or slightly reducing flame should be used in conjunction with a suitable rod and flux. The rods should be clean and coated with flux. The flux is corrosive and it should be removed and the surface protected with a special chemical treatment like chromating.

Magnesium oxidizes readily when heated, and ignites if overheated. The use of proper flame and a suitable flux pasted on rod and on the bottom and top surface of the joint will tend to prevent firing. A magnesium fire should be extinguished by sand — not by water.

NOTE — It is sometimes difficult for the operator to decide whether he has an aluminium or a magnesium alloy casting for repair. If there is any doubt, mix a small

amount of ammonium chloride with water and sprinkle on the (cold) casting; if there is no reaction, the casting is aluminium, but if the beads of solution begin to 'fizz' it is a magnesium alloy casting. The solution should be rinsed off with water immediately after the test.

7.10 Repair of Castings

7.10.0 *General* — One of the important applications of gas welding process is repair of castings. This is because of the control in the heat input that could be exercised by the welder while manoeuvring the welding blowpipe. Some useful hints on repair of castings are given in **7.10.1** to **7.10.4**. Reference may be made to IS : 5139-1969* for further information.

7.10.1 *Inspection of Castings and Preparation for Welding* — A casting received for welding shall be thoroughly cleaned, degreased and inspected for cracks. Any undetected crack will expand further during welding. It is, therefore, essential to examine the casting thoroughly.

When the casting thickness is above 5 mm, a 90° 'Vee' preparation should be made. A small hole should always be drilled a little beyond the visible end of the crack. When 'veeing' a crack, the Vee should also be taken beyond the visible end of the crack. On material above 12 mm thickness, it is preferable to have double 'Vee' preparation.

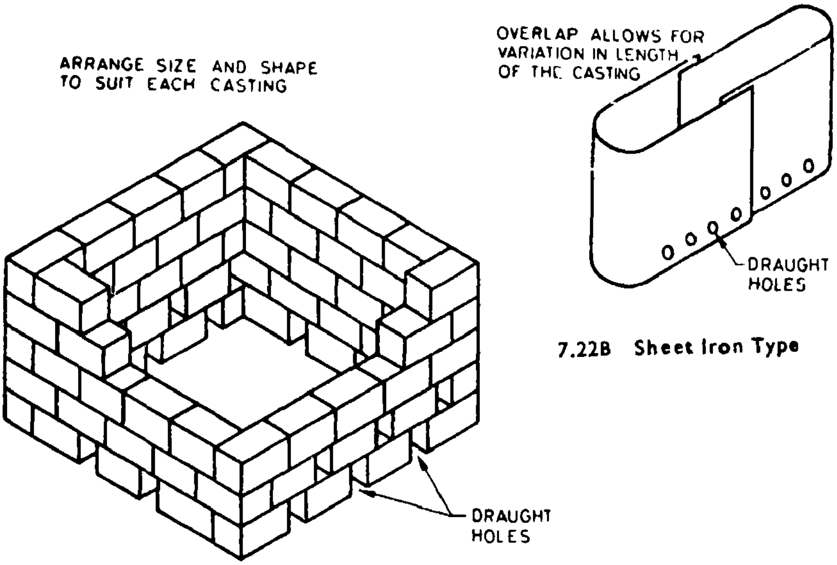
When iron casting is prepared for braze welding, sharp edges of the 'Vee' should be rounded off. Ground surfaces do not 'tin' properly. Such surfaces may be filed with a rough file. Cleaning by sand blasting is an ideal preparation for braze welding.

For fusion welding of thin castings, a welder of average skill can scrap out a groove on cast iron with the welding rod (or on aluminium with a steel scraper) as soon as the edges start melting and before adding the filler rod.

7.10.2 *Preheating* — Cast metals (except malleable cast iron) are relatively non-ductile, that is, they will break rather than bend. When only a portion of metal structure is heated as in the case of welding — the expansion and contraction of the heated portion is resisted by the cooler portions. Wrought metals, being ductile, accommodate themselves to this by bending and buckling. Cast metals, however, cannot do this, thus resulting in further fracture. To overcome such a trouble a casting should normally be preheated.

Small castings may be preheated by application of the blowpipe flame before commencing the weld, but larger work should be preheated in a furnace. A simple form of preheating furnace can be built from a number of fire bricks as shown in Fig. 7.22A. The stack iron type furnace is illustrated in Fig. 7.22B. A blacksmith's forge or use of coke is not recommended for preheating due to danger of sulphur from coke entering the weld and heat concentration. The furnace should be constructed in a place free from air draughts. If necessary, a screen should be used at a distance from the furnace to prevent disturbance from strong winds.

***Recommended procedure for repair of grey iron castings by oxy-acetylene and manual metal arc welding.**


ARRANGE SIZE AND SHAPE TO SUIT EACH CASTING
DRAUGHT HOLES
OVERLAP ALLOWS FOR VARIATION IN LENGTH OF THE CASTING
DRAUGHT HOLES

7.22A Brick Type

7.22B Sheet Iron Type

FIG. 7.22 TEMPORARY PREHEATING FURNACES

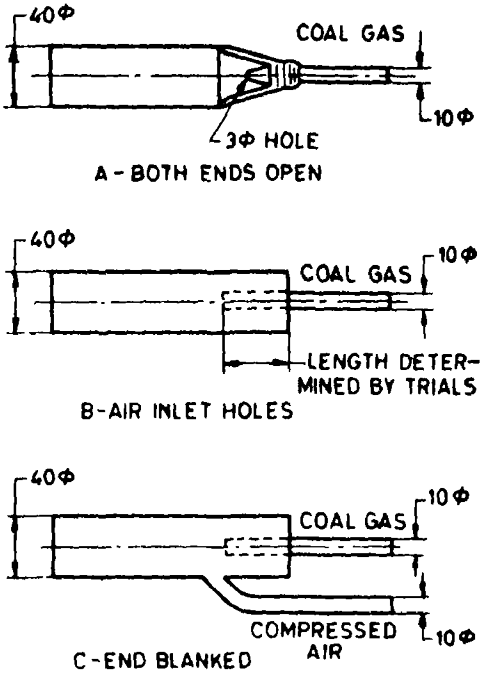
Place the casting inside the furnace on a few fire bricks to allow heat to spread beneath it and provide adequate support so as to prevent ' sagging ' when it is hot. The surface to be welded should be horizontal and there should be provision, if necessary, for moving the casting. Fuel used is usually charcoal and it is placed in the furnace all around the casting (but not on bottom and top) in sufficient quantity. After the charcoal has been ignited, the top should be covered with asbestos sheet. Vent holes should be arranged at regular intervals between the lower courses of bricks, and the fuel should be arranged to give more heat to the heaviest parts of casting.

When coal gas is available, it can be used in the form of bunsen burners which can be constructed from lengths of gas barrels (*see* Fig. 7.23).

For casting of moderate sizes a preheating table may be used, because it enables the welding to be carried out at convenient height. Bright parts in castings can be protected with graphite.

7.10.2.1 *Local preheating* — It is often possible to save time and fuel by preheating the points (*see* Fig. 7.24 and 7.25) which would be stressed by expansion and contraction of the weld. The points to be preheated are those at which the casting would break if a wedge were driven through the fracture. For example the ring shown in Fig. 7.24 would break at *C* if the wedge *B* is driven in the opening at *A*. *C* is, therefore, the point to be preheated.

There are a few cases when welding may be carried out without preheating as in the case of joining two pieces of cast metal bar or tube where the joint is not restricted.



All dimensions in millimetres.

Fig. 7.23 Burners for Preheating

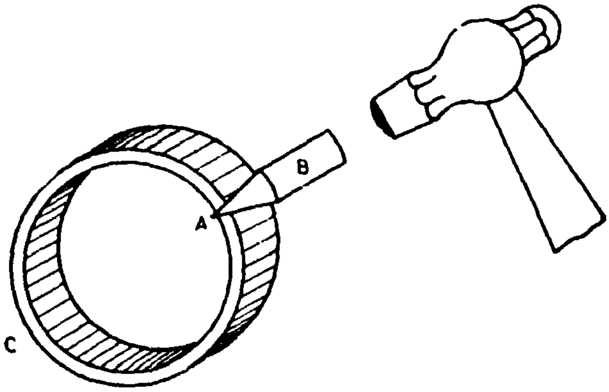


Fig. 7.24 Local Preheating

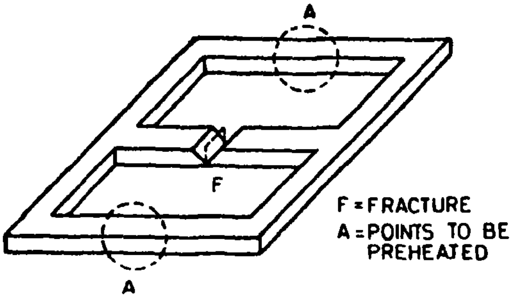


Fig 7.25 Example of Local Preheating in Order to Separate Welding Edges

7.10.2.2 *Preheating temperatures*

a) *Fusion welding cast iron* — approximately 700°C, that is, dark cherry red. By using a tube as telescope (or by throwing a shadow across it) the colour of the preheated casting can be seen correctly. Do not put the end of the tube right into the furnaces as the heat will draw through the tube and may burn the operator's eye.

b) *Bronze welding of cast iron* — approximately 400°C indicated by the melting of a stick of solder of charring of wood shavings in contact with the casting preheated.

c) *Aluminium and magnesium alloy casting* — 350-400°C indicated by charring of saw dust or melting of a soft solder stick by rubbing on preheated casting.

d) *For castings in general* — for fusion welding — within 400°C to 500°C of the melting point.

7.10.3 *Welding* — A casting preheated in furnace, should be welded in the furnace only exposing the portions of the casting required to be welded. Other portions should be kept covered. If necessary, charcoal may be added to maintain the heat and necessary arrangement made to protect the operator, from the radiated heat.

7.10.4 *Post Cooling* — On completion of the weld, the casting should be very slowly cooled by keeping it in the furnace, covering the top and all the draught holes at the bottom. If necessary, some amount of charcoal may be added in the furnace to reduce the rate of cooling. Casting should be taken out of the furnace only when it is cooled to ambient temperature. Castings locally preheated or heated with coal gas or preheated with a blowpipe can be slowly cooled by enclosing them under dry lime.

SECTION 8

OXYGEN CUTTING

8.1 General

Oxygen cutting is indispensable in industry today and in this sense perhaps the greatest event in the field was the discovery around the year 1885 by Mr Thomas Fletcher, of Warrington, England, that steel could be cut by means of a jet of oxygen directed on to a portion of it previously heated to red heat. Although the possibility of oxygen cutting was appreciated as early as in the year 1885, its commercial application started 20 years later. Since then oxygen cutting has produced far reaching changes in the industrial practices relating to cutting and shaping of steel. It is interesting to record that bankers and leading safe manufacturers made a serious protest against the introduction of such apparatus, which they considered could only be used for felonious purposes. And curiously, they were not wrong; the first practical use of oxygen cutting was made in opening a safe in London Post Office in the year 1901 while at a later date a safe in a German Bank was opened in a similar manner.

8.2 The Process

Oxygen cutting is primarily a chemical process relying on the marked chemical affinity of oxygen towards ferrous metals, when raised to or above the ignition temperature. Advantage is taken of this principle by means of the cutting blowpipe, which provides the method of supplying high purity oxygen and a suitable fuel gas to preheat the metal to the required temperature. The reaction that takes place is that when a jet of high purity oxygen strikes steel previously heated to its ignition temperature, combustion takes place with generation of considerable heat at the point where oxygen strikes the metal. The heat thus generated, together with that supplied in the preliminary heating, is sufficient to melt the iron oxide produced by combustion. The slag or oxide, as produced, is blown out of the zone by the cutting oxygen jet. As the slag is blown away the cutting oxygen jet is moved, thus forming a narrow cut or 'kerf'. Since only the metal within the direct path of the oxygen jet is acted upon, a remarkable degree of accuracy can be achieved in this cutting process.

The cutting process, therefore, involves three functions:

a) Raising the steel locally to a temperature at which ignition can start. This is called 'preheating' and the steel has to be brought to a temperature of about 900°C.

b) Applying a jet of high purity oxygen of correct volume and velocity to cause oxidation of the iron in the path of the jet.

c) The removal of oxide particles from the line of cut by means of kinetic energy of the oxygen jet and moving the jet for progress of the cut.

8.2.1 Although theoretically, once cutting has commenced, heat of reaction should keep the process going without external sources of heat, in practice preheating cannot be dispensed with.

The suitability of a metal or an alloy for oxygen cutting is governed by the following considerations:

a) The metal should be capable of being oxidized at a temperature lower than its melting point, and

b) The oxides produced should be fusible at a temperature lower than that generated by the reaction.

Theoretically, 300 litres of oxygen are required to oxidize completely 1 kg of iron to Fe_3O_4. Acutally, in the cutting of ordinary steel, the consumption varies from 62 to 170 litres of oxygen per kg of iron removed from the cut. In addition to the iron oxidized during cutting, some iron is removed by melting and by the erosion or scrubbing effect of the cutting oxygen stream and the iron oxide flowing from the cut. Analysis of the slag has shown in some instances over 30 percent to the iron which has not been oxidized.

8.3 Cutting Blowpipe — Oxygen cutting is accomplished by means of a cutting blowpipe with a suitable nozzle that will supply a flame for heating a spot on a piece of iron or steel to the correct preheat temperature and also provide a stream of high purity oxygen under pressure so that the oxidation of the metal will start in a narrow slot (kerf) extending entirely through the base metal. The cutting blowpipe is provided with valves and regulators to control the flow of oxygen and fuel gas. The operating principles of a cutting blowpipe are given in Fig. 8.1. A typical cutting is shown in Fig. 8.2. Acetylene is the most extensively used fuel gas in oxygen cutting although hydrogen, propane, LPG, coal gas, coke oven gases are also used.

8.3.1 Although, in principle, the cutting blowpipe needs only one preheat flame, this would make it difficult to change the direction of cutting, because preheating must take palce ahead of the cutting oxygen jet. The cutting nozzle is, therefore, provided with an annular ring or a ring of small openings (usually four or more in number) surrounding the cutting oxygen orifice. The preheat flame, therefore, surrounds the cutting oxygen jet. The nozzle may either be a two-piece nozzle consisting of an inner and an outer nozzle or be a single piece nozzle. This arrangement of the preheat flame permits the cutting blowpipe to be moved in any direction without losing the effect of the preheat flame. The nozzles used for cutting sheet metals, generally referred to as ' sheet-metal nozzles ' often have only one preheat flame orifice which when the cutting blowpipe is moved precedes the cutting oxygen jet.

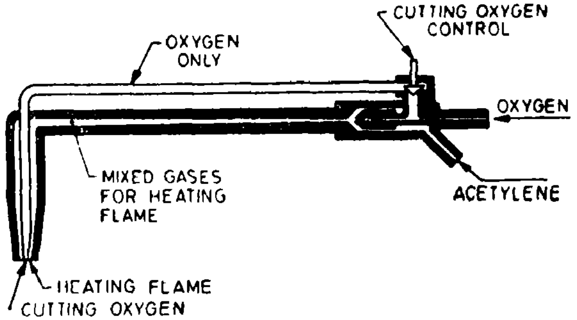


FIG. 8.1 OPERATING PRINCIPLE OF OXY-ACETYLENE CUTTING

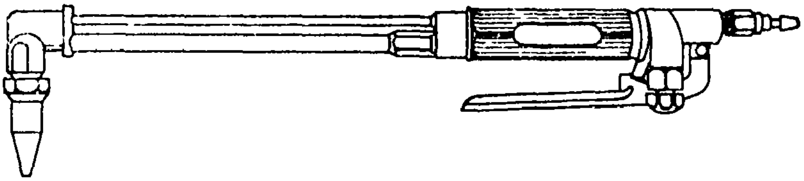


FIG. 8.2 A CUTTING BLOWPIPE

8.3.2 There are mainly two types of cutting blowpipe, high pressure and low pressure, the distinction refers to the fuel gas pressure range required for the preheat flame. If the minimum fuel gas pressure required is 0·15 kgf/cm^2 or more the blowpipe is known as ' high pressure blowpipe '. When the required pressure is less and the fuel gas has to be drawn to the preheat flame with the aid of an injector incorporated in the blowpipe, it is designated as ' low pressure ' or ' injector ' type blowpipe. The injector type cutting blowpipe can also be used with high pressure fuel gas supply and hence these are often referred to as ' universal ' type cutting blowpipes.

Metal can be cut either by the hand guided cutting blowpipe or by means of electrically-driven or hand-operated automatic cutting machines. The former is generally known as ' hand ' or ' manual ' cutting and the latter as ' machine ' cutting.

8.3.3 *Hand or Manual Cutting Equipment and Methods of Assembly*

8.3.3.1 *High pressure (HP) equipment, using dissolved acetylene* — High pressure oxy-acetylene hand-cutting equipment requires the following:

a) Supply of acetylene in cylinders or from pipeline,

b) Supply of oxygen in cylinders or from pipeline,
c) Cutting blowpipe with necessary nozzles,
d) Acetylene pressure regulator,
e) Oxygen pressure regulator,
f) One length each of oxygen and acetylene rubber-canvas hose,
g) Hose clips,
h) Spanners and spindle keys,
j) Welders' goggles and protective gloves,
k) Spark lighter, and
m) Trolley for accommodating complete equipment and cylinders, if necessary.

8.3.3.2 *Low pressure (LP) equipment* — Low pressure cutting equipment is almost identical to HP equipment except that instead of acetylene cylinder and regulator, an acetylene generator of suitable capacity and a ' low pressure ' cutting blowpipe with necessary cutting nozzles are required. The acetylene generator being bulky cannot be normally moved about and hence a trolley is not generally necessary.

8.3.3.3 *Assembly* — Both the HP and LP equipment are assembled exactly as HP and LP welding equipment, but the following points should be remembered.

8.3.3.4 *Lighting the HP cutting blowpipe* — After fitting the correct size of cutting nozzle to the blowpipe, open the cylinder valve and set the working oxygen pressure on the regulator with the heating and cutting oxygen valves of the blowpipe open. Shut the oxygen valves of the blowpipe; then set the acetylene working pressure on the regulator. The choice of the correct size nozzle and settings of the pressures on the regulators should be made in accordance with the recommendation of the blowpipe manufacturer.

Open the acetylene valve slowly and ignite the gas with a spark lighter. Open the heating oxygen valve and slowly adjust the flame to neutral. Now press the cutting oxygen control lever and again adjust the heating control to give a neutral flame. Close the cutting oxygen control valve and the blowpipe is now ready for use.

On completion of the work, close the oxygen cutting valve, then the acetylene and heating oxygen valves. Close the cylinder valves and release the pressure on the pressure regulator control springs by slackening the pressure adjusting screw.

8.3.3.5 *Lighting the LP cutting blowpipe* — Before lighting up, check that the generator is charged with the correct size and quantity of carbide and filled with water in accordance with the manufacturers' instructions and that the hydraulic back pressure valve is filled with water to the correct level.

Set the oxygen pressure as for HP equipment. Open the preheat oxygen valve on the blowpipe and then acetylene as for HP equipment. For stopping the work, follow the same procedure as for HP cutting blowpipe.

8.3.3.6 *Pressure regulators for cutting* — Select regulators which are capable of supplying oxygen and acetylene at required pressures and in sufficient volumes.

8.4 Procedure for Hand Cutting

8.4.1 *Precautions* — Before starting the cut, the operator must ensure that:

a) there is no inflammable material around the place of work;

b) if the article to be cut is a drum or a pipe, it does not contain even traces of combustible material or any gas or vapour under pressure;

c) he is protected from fire and sparks; and

d) he is wearing the right type of goggles.

8.4.2 *Preparation of the Metal Surface* — The metal surface where the cut is to be made, should be cleaned off paint, tar or heavy scale. Otherwise the fumes will cause considerable discomfort to the operator. Burning of these substances produce scale which may block the nozzle. It is a good practice to pass the preheat flame along the line of cut prior to cutting. This followed by wire-brushing will make the line of cut clean of scales.

8.4.3 *Square Edge Cutting* — Insert the correct size of nozzle, adjust the pressures and light the blowpipe. Hold the blowpipe at one edge of the plate and at right angles to it. The tip of the preheat flame should be about 1·5 mm above the plate surface. When the spot under the flame is bright red, release the cutting oxygen. When the cut is through move the blowpipe along the line of cut at a uniform speed depending on the plate thickness. The speed of cutting should be just fast enough so that the cut continues to penetrate the plate completely without excessive oxidation or melting. A suitable guiding device is of great value for efficient operation, particularly to the less experienced operators.

If the blowpipe is moved too slowly the preheat flame tends to melt the edges of the cut producing a ragged appearance. If the speed is too fast the cutting oxygen will fail to pierce the plate and cutting will, therefore, be incomplete.

Operating data for cutting mild steel using a typical cutting blowpipe is given in Table 8.1.

The data is intended to serve as a guide only and may vary to suit local conditions.

Acetylene pressure should be not less than 150 mm H_2O. If dissolved acetylene from a cylinder is used, the pressure should be 0·15 kgf/cm^2.

TABLE 8.1 OPERATING DATA FOR CUTTING MILD STEEL

(*Clause* 8.4.3)

DIAMETER OF CUTTING OXYGEN ORIFICE (1) mm	THICKNESS (2) mm	CUTTING OXYGEN PRESSURE (3) kgf/cm²
0·8	3- 6	1·0-1·4
1·2	6- 19	1·4-2·1
1·6	19-100	2·1-4·2
2·0	100-150	4·2-4·6
2·4	150-200	4·6-4·9
2·8	200-250	4·9-5·5
3·2	250-300	5·5-5·6

It may be mentioned here that the volume of gases necessary for the cut without interruption should be assessed at the outset and proper arrangement be made for regulators capable of supplying gases at the rate required. If necessary, a manifold of several cylinders should be commissioned.

While cutting round bars, nick the bar with a chisel at the point where a cut is to be started. Alternatively, place a red hot steel wire touching a point on the surface of the bar and release the cutting oxygen stream at the point of contact to initiate cutting.

8.4.4 *Painted and Galvanized Plates* Clean the surface as much as possible before the cut and, if possible, use a respirator. The procedure is as outlined for square edge cutting.

8.4.5 *Cutting Holes* — Hold the blowpipe at right angles to the plate on the point where a hole is to be made. When the point is bright red release cutting oxygen slowly. Raise and tilt the nozzle slowly so that the sparks may not foul the nozzle. Thus a hole may be pierced. If a big hole, circular, rectangular or of any other shape is to be cut, first of all make an outline of the hole. Then pierce a hole at the centre and proceed with cutting along the outline.

8.4.6 *Bevelling* — Now-a-days bevelling is almost exclusively done by machine cutting. But with some practice it should not be difficult for an operator to cut bevels on steel plates manually. This is done by holding the blowpipe head in such a way that the oxygen streams through the plate at the desired angle. It is obvious that the angle between the nozzle and the plate must remain constant, and this poses the greatest difficulty for the beginner. The position of the preheat flame relative to the plate surface is very important. It will be found that if the preheat flame is either too close or too far from the top surface, the cut will not be as good as when it is moved along at the proper distance above the plate surface. For a good bevel cut a steadier hand and good practice than required for square edge cutting is needed. It should be mentioned here that the preheat flame should be stronger and cutting oxygen pressure higher for bevelling than required for square cutting same thickness of plate. A guiding device may, in this case, be very profitably used.

8.5 Heavy Cutting — Heavy cutting may be arbitrarily defined as cutting of steel in the thickness range 300 to 2 000 mm. An important point to be understood in connection with heavy cutting is that contrary to what might be assumed high pressure is not required. Nor is it necessarily true that the cutting oxygen pressure should be increased with the increase in thickness to be cut. Cutting oxygen pressures in the range 0·5-3·5 kgf/cm^2 measured at the entry of cutting orifice have been found adequate for the purpose. Typical data based on flow rate of oxygen for heavy cutting of steel is given in Table 8.2. However, the operators should normally be guided bv the data given by the manufacturers.

TABLE 8.2 OPERATING DATA FOR HEAVY CUTTING OF STEEL

THICKNESS	FLOW OF OXYGEN	DIAMETER OF CUTTING ORIFICE	CUTTING OXYGEN PRESSURE AT ORIFICE
(1)	(2)	(3)	(4)
mm	l/h	mm	kgf/cm^2
400	42 450- 56 600	4·84- 7·25	1·75-3·43
600	45 280- 84 900	5·33- 8·30	1·54-3·36
800	75 880-118 860	6·25-11·25	1·12-2·80
1 000	96 220-141 500	8·25-13·75	0·70-2·31
1 200	127 350-169 800	10·55-15·00	0·49-1·89

The speed of cutting is between 50 and 150 mm per minute. The following points are to be kept in view during heavy cutting:

a) The equipment must be designed to carry the high volume of oxygen required for heavy cutting; and

b) The preheat orifices should be such that the preheat flame is strong and as long as possible.

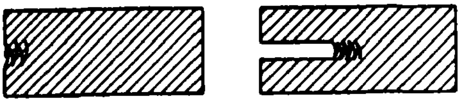
8.6 Cutting of Cast Iron — Strictly speaking cast iron cannot be cut by the usual oxygen cutting process in the sense the term is used for cutting mild steel. Fortunately in most cases cast iron is cut only for demolition purposes where severing by any means rather than quality-cut is required. This, however, can be achieved by suitable modification to the flame and technique of the cutting process.

The content of carbon in cast iron is generally around 3 percent and quite a large part of it is present as graphite in the case of grey cast iron. In addition cast iron contains a good percentage of silicon. Neither of these elements is easily oxidizable and silicon, when oxidized, forms the refractory silicate which prevents the cutting oxygen stream from coming in contact with hot iron to keep the cutting operation going. White cast iron, in which most of the carbon is in the combined state, is also difficult to cut by the normal process.

It has, however, been found that a carburizing preheat flame together with oxygen at a higher pressure and volume than required for cutting same thickness of mild steel helps to form the graphite and silicon present in the cast iron into a fusible slag which is blown away by the comparatively high oxygen pressure. A wider area is required to be preheated to get the necessary benefit of heat due to oxidation of iron. The cutting oxygen pressure is about twice that required for cutting mild steel of same thickness. The cut obtained by this process is obviously ragged and the kerf much wider. Due to the nature of the flame necessary only dissolved acetylene can be used as fuel gas. The heat developed and smoke generated in the process are also high.

8.6.1 *Procedure* — Select proper nozzle, adjust the correct gas pressures to the required values with the valves open and light the preheat flame. The acetylene feather should be about 2 to 2·5 times longer than the central white cone with the cutting oxygen valve open. Preheat one end of the job with a swinging movement of the nozzle approximately 6 mm each way of the line of cut, with the tip of the nozzle about 8-12 mm above the surface. When the area is bright red, release oxygen, the angle of the cutting oxygen stream being about 45° with the line of cut. The cut is continued with the swinging semi-circular movement and the angle is gradually increased to about 75°. If the cut is stopped, stop cutting oxygen, go back to the preheating zone and heat it with the same swinging movement of the blowpipe. Start the cut preferably from one edge of the kerf. Should the cut cease to continue, put the red hot end of a mild steel rod at a difficult point of the cut and release cutting oxygen. This will help restarting of the cut.

Operating data for cutting cast iron using a typical blowpipe is given in Table 8.3. The data is intended to serve as a guide only and may vary to suit particular applications.



PREHEATING

BLOWPIPE MOVEMENT DEVICING PROGRESS OF CUT

FIG. 8.3 METHOD OF BLOWPIPE MANIPULATION

TABLE 8.3 OPERATING DATA FOR CUTTING CAST IRON

(*Clause* 8 6.1)

THICKNESS	DIAMETER OF CUTTING OXYGEN ORIFICE	OPERATING PRESSURE		GAS CONSUMPTION		
		Oxygen	Acetylene	Acetylene	Heating Oxygen	Cutting Oxygen
(1)	(2)	(3)	(4)	(5)	(6)	(7)
mm	mm	kgf/cm²	kgf/cm²	l/h	l/h	l/h
100-150	2 4	5 6-6 3	0 6	2 800 3 400	2 600-3 100	19 500-21 800
200-250	3 2	6 3-7 7	0 6	4 400 5 100	4 000-4 500	28 300-34 000
300-350	4 0	Over 10 6	0 6	Over 6 800	Over 6 100	Over 58 100

8.7 Oxygen Lancing — For cutting or boring holes in very thick steel or cast iron, for breaking up furnace, scrap or spills or clearing frozen tap holes of furnaces, the ordinary cutting blowpipe is inadequate For such work oxygen lance is necessary The lance consists of a length of 3 15, 6 3 or even 10 mm size steel gas pipe suitably connected to an oxygen regulator There is no provision for a heating flame

To start the cut, hold the end of the lance tube a short distance away from the spot where the cut is to be started, heat the starting point with a separate welding or cutting blowpipe and, when the starting point is hot enough, heat the end of the lance to red heat and turn the oxygen on and remove the heating blowpipe Oxidation starts and the burning end of the lance furnishes sufficient heat to continue cutting operation and also to keep the oxide fluid so that it will flow out of the cut In cutting or boring a hole, work the lance up and down or forward and backward — like a saw — in the kerf in order to extend the cut

During oxygen lancing a shield should be used for protection against flying slag, especially when boring holes

8.8 Flame Gouging — Flame gouging provides a rapid and accurate means for removing a narrow strip of surface metal from steel plate, forgings and castings It differs from other flame processes in that cutting action does not progress right through the thickness of the material but is confined to a narrow groove This is achieved by delivering a relatively large volume of oxygen at low velocity through a specially designed nozzle at a low angle so that a smooth, accurately defined groove is cut. The principle is the same as that of oxygen cutting, that is, ignition of steel in a stream of oxygen. Therefore, all steels which can be flame cut can also be flame gouged.

A suitable blowpipe with nozzles of different sizes is made use of for cutting grooves of different shapes and depths. The nozzles have preheating flames so arranged around the central divergent oxygen orifice as to provide the required preheat and to maintain the thermal balance in progressive gouging. The flames are initially directed at a steep angle of about 20° to the horizontal and when the spot where gouging is to start is red hot the cutting oxygen stream is released. When the groove starts the angle of the blowpipe is reduced to the normal operating angle of about 5° to the horizontal.

Gouging is about three times as fast as chipping. Some of the common applications of gouging are : (a) removing root side of welds prior to depositing a sealing run; (b) removing defective spots in welds for rectification; (c) edge preparation for single U and double U groove weld; (d) for maintenance operations, such as removing steel tubes seized on mandrils; (e) dismantling welded structures without damaging the parent plates; and (f) for removing surplus metal such as reinforcements on welds and for shaping steel castings. Gouging may also be used to remove rivet heads without damaging the parent plates. A special rivet washing nozzle should be used for the purpose.

8.9 Under-Water Cutting — With hydrogen as fuel gas, oxygen cutting process may also be used for cutting steels under water, up to a depth of 30 m. Special cutting equipment is however required for under-water cutting operations.

8.10 Machine Cutting — Mechanization of blowpipe eliminates the uncertainties and irregularities inseparable from hand cutting. A very wide range of machines is available to suit different purposes. From the simple single purpose machines intended for cutting straight lines and circles to the sophisticated machines designed for production of irregular shapes in steel plates or forgings, a very wide range of different types of cutting machines have been developed. Machines falling in the latter category vary in so far as methods employed for regulating the movements are concerned, but the fundamental principles governing the adjustment of the oxygen supply and cutting speed are the same whatever the type. Uniform speed of travel and percise control over nozzle size, heating flame and cutting oxygen pressure enable a very high degree of accuracy, efficiency and economy to be achieved (*see* Fig 3.9 and 3.10).

8.11 Effects of Alloying Elements on Oxygen Cutting of Steels

8.11.1 It is known that oxygen cutting causes an increase in the surface hardness of the cut edge, the degree of hardness increasing with increasing percentages of carbon in the steel. For all practical purposes the hardening effect is negligible on steels up to 200 mm thick having a maximum carbon percentage of 0·3 percent. Steel with higher carbon contents should be preheated. The degree of preheat is higher with higher percentages of carbon.

The effect of other alloying elements is given below:

a) *Manganese* — Steels containing up to 14 percent manganese and 1·5 percent carbon can be cut without difficulty and the cutting should be at the highest possible speed compatible with a good cut and the job should be cooled as rapidly as possible.

b) *Silicon* — Silicon, in amounts usually present has no effect. Transformer irons having about 4 percent silicon are readily cut. Silicon steels containing considerable amounts of carbon and manganese should be preheated and post-annealed.

c) *Chromium* — Steels having up to 5 percent chromium can be cut without much difficulty. Where higher chromium contents are involved powder cutting should be employed.

d) *Nickel* — Steels containing up to 7 percent nickel can be cut readily; steels with nickel content 20 to 30 percent, may also be cut if carbon content is not too high.

e) *Molybdenum* — Molybdenum has the same effect as chromium. Aircraft quality chromium-molybdenum steel offers no difficulty. High molybdenum-tungsten steels should, however, be cut by the powder process.

f) *Tungsten* — Usual alloys containing about 12-14 percent tungsten can be readily cut; but cutting is difficult with higher percentage of tungsten. The limiting percentage is about 20.

g) *Copper* — In amounts up to 2 percent copper has no apparant effect.

h) *Aluminium* — Unless present in large amounts (of the order of 10 percent) the effect of aluminium is not appreciable.

j) *Phosphorus* — This element has no effect in amounts tolerated in steel.

k) *Sulphur* — Small amount, as is present in steels, have no effect. Rate of cutting is reduced and sulphur dioxide fumes are noticeable when the percentage of sulphur is high.

m) *Vanadium* — In amounts usually present in steel, this rather improves the quality of cut.

8.11.2 The cutting process also has an influence on the degree of hardness. While milling produces least affect, depth of hardness produced by shearing is maximum. The depth of hardening produced by various cutting processes is given in Table 8.4 for guidance.

8.12 Powder Cutting

8.12.1 *General* — As stated earlier the foremost requirement of oxygen cutting is that the melting point of the oxide should be lower than that of the material being cut. While in the case of low carbon steels this requirement is fulfilled, the oxides produced during cutting stainless steels and non-ferrous materials have a higher melting point than that of the parent metal. The alloying element like chromium in the stainless steels and the constituents of non-ferrous materials readily combine with oxygen at high temperatures. The resulting oxides, which are refractory in nature, form a thin tenacious

TABLE 8.4 DEPTH OF HARDENING PRODUCED BY VARIOUS CUTTING PROCESSES

(*Clause* 8.11.2)

CUTTING PROCESS	MAXIMUM DEPTH OF HARDENING	
	Mild Steel	Low Alloy Steel
(1)	(2)	(3)
	mm	mm
Shearing	11·25	6·50
Oxy-propane	6·00	3·50
Oxy-coal gas	4·00	3·75
Oxy-acetylene	4·75	2·00
Cold-sawing	1·75	1·00
Milling	1·25	1·00

film on the surface of the metal thus preventing further oxidation of the material. It is, therefore, difficut to cut the high alloy steels and non-ferrous material using normal oxy-acetylene cutting process.

Until the introduction of powder-cutting process mechanical methods like shearing and machining were being used to cut and shape high alloy steels including heat and corrosion resisting steels. Mechanical methods being relatively slow and expensive add considerably to the cost of fabrication of the already costly group of materials. Powder cutting process can be used to cut, bevel and profile stainless and other high alloy steels at similar speeds and with much the same ease as could be obtained by oxygen cutting of low-carbon steels.

8.12.2 *Powder Cutting Process* — In the powder cutting process oxy-fuel torch is supplemented by a stream of powdered material. Finely divided iron-rich powder is separately introduced into the reaction zone by compressed air or nitrogen. The combustion of iron powder increases the temperature of the reaction zone. This will increase the fluidity of the refractory oxides which are removed by the combined melting and fluxing action and also to a certain extent by the eroding action of the iron particles. A clean surface is thus continuously exposed to the stream of oxygen and the cut progresses through the thickness of the metal. The quality of cut obtained is only slightly inferior to the cut obtained by oxy-acetylene process in low-carbon steel.

8.12.3 *Equipment* — The process requires the use of a powder dispensing unit to introduce iron powder into the reaction zone. The dispenser should be capable of giving a constant rate of flow at any given set of conditions. Through suitable controls it should be possible to regulate the rate of flow of the powder.

The powder dispenser (*see* Fig. 8.4) is essentially a pressure vessel of injector type, incorporating a hopper, air filter, air pressure regulator, drier and injector unit. The dispenser cover which may be removed to permit changing of hopper is fitted with a relief valve set to blow at a predetermined pressure. The dispenser is also provided with a screen for removing oversize particles from powder and a shallow tray for holding a suitable drying agent.

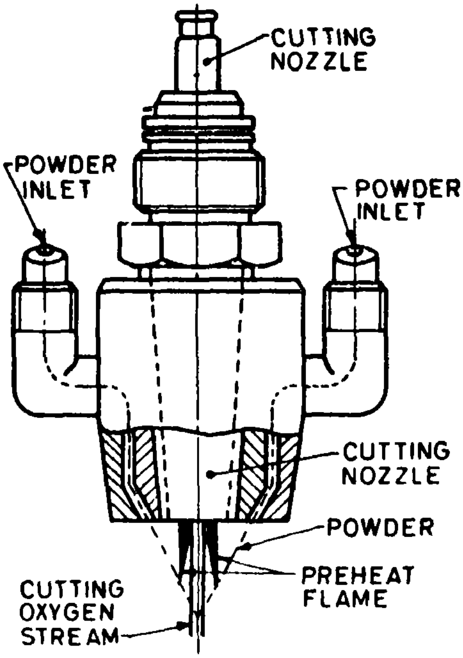


Fig. 8.4 The Powder Nozzle Showing its Method of Operation

Compressed air fed through the dispenser picks up the powder as it passes through the injector unit. The air-powder mixture is carried to the blowpipe by means of rubber hoses.

8.12.3.1 *Hand cutting attachment* — The powder is introduced into the reaction zone by means of powder cutting attachments fitted to normal oxygen cutting manual blowpipes. The attachment comprises of powder valve, powder nozzle (*see* Fig. 8.4) and connecting tubing. The powder nozzle is fitted over the standard cutting nozzle and powder valve is clamped in a suitable position adjacent to the gas valves. Iron powder is injected through heating flame into the cutting zone at a point approximately 25 mm below the surface of the nozzle. The cutting nozzle (usually one size larger than for equivalent thickness of carbon steels) is positioned as for cutting maintaining a clearance of 25 to 35 mm between the nozzle and the work to permit the powder to mix and burn with the oxygen in the cutting stress.

8.12.3.2 *Attachments for machine cutting* — Powder cutting attachments for machine cutting stainless steel up to 300 mm thick have been developed. With suitable modifications these may be fitted to various straight line and profile cutting machines.

8.12.3.3 *Single tube and multijet attachment* — The powder attachments are available in two types. In the first type a single tube leads to the cutting nozzle and discharges a single stream of powder into the cutting oxygen (*see* Fig. 8.5). In many cases particularly for manual cutting or straight line machine cutting the powder cutting attachment is eliminated and a single tube is substituted. This tube discharges the powder stream at an angle to the cutting oxygen jet at a velocity sufficient for it to reach the heating flame. The single tube attachment can be used only when cutting is being done in one direction, for the powder must in all cases lead the cutting oxygen stream.

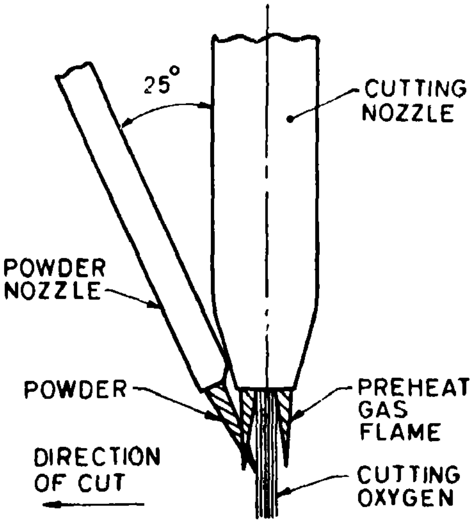


Fig. 8.5 Single Tube Powder Feed

In the multijet type (*see* Fig. 8.4) the gas-powder mixutre is carried from the down stream side of the powder valve to a powder cutting adaptor attached to the cutting tip. This adaptor surrounds the periphery of the exit end of the tip. General powder jets cause the powder to issue in the form of a cone and at sufficient velocity to blow thorugh the preheating flame and impinging against the cutting oxygen stream.

All powder cutting attachments are designed to be wear resistant, but because of the abrasive nature of the iron particles some wear is unavoidable in the parts coming in contanct with the powder.

8.12.4 *Compressed Air Requirements* — The dispenser should be supplied from a source of clean and dry air. Actual dispenser operating pressure varies from 0·070-0·70 kgf/cm^2 but usually between 0·21 and 0·42 kfg/cm^2. Approximate consumption of air at different operating pressures are given below :

Pressure	*Consumption*
kgf/cm^2	l/h
0·14	700
0·35	850
0·50	1 000
0·70	1 100

Oxygen shall not in any circumstances be used in place of air for operating the dispenser.

8.13 Powder Cutting of Different Materials

8.13.1 *Stainless Steel* — In general the principles of cutting stainless steel are the same as those used in oxygen cutting of mild steel. It is the general practice in powder cutting to use nozzles a size higher than that required to cut mild steel of same thickness using oxygen cutting process. A greater distance is maintained between the nozzle and the plate surface to permit thorough combustion of the powder at the reaction zone.

The preheating time needed in normal oxygen cutting is eliminated in powder cutting. Due to intense heat produced by combustion of iron powder, it is possible to make fast cuts when cutting cold material without losing time required for preheating.

8.13.2 *Cast Iron and High Alloy Steels* — For cutting cast iron operating principles are the same as for stainless steel of equal thickness, but speed of cut will be less by about 50 percent. Similar reduction in speed would be noticed while cutting high alloy steels.

8.13.3 *Copper and Copper Alloys* — In the case of copper and copper alloys powder cutting process is found to be effective because of the melting action coupled with the eroding action of high velocity particles of iron powder rather than due to oxidation. An important factor to be considered while cutting copper and copper alloys is the high thermal conductivity of the material being cut. Due to rapid dissipation of heat large amount of preheat is required to maintain the metal at a sufficiently high temperature to enable the cut to progress.

8.13.4 *Nickel and Nickel Alloys* — Although not having the high thermal conductivity of copper, nickel has comparatively high melting point. Considerably higher preheating temperatures and use of heavy duty blowpipe are, therefore, necessary to cut nickel and nickel alloys. However, nickel alloys such as nimonic and inconel are much more readily cut than certain other alloys, preheating being unnecessary.

8.13.5 *Aluminium and Aluminium Alloys* — In the case of aluminium and aluminium alloys the quality of cut obtained by powder cutting can only be described as fair. While with pure aluminium ragged cut is obtained, in the case of certain alloys the cut face is very hard due to formation of oxides which extend to a depth up to 6 mm depending on the thickness of the material.

8.13.6 *Heavy Cutting* — For heavy cutting of stainless steels, heavily encrusted open-hearth spills, ladle buttons, etc, blowpipes with appropriate powder cutting attachments are available. Nevertheless certain innovations are necessary in cutting extra-thick castings.

8.13.7 *Powder Washing* — A development of powder cutting process, powder washing relates to a thermal method of fettling steel castings. By powder washing, burnt-on and metal-penetrated mouldings can be attended to much more quickly than is possible by conventional tools.

8.13.8 *Powder Gouging* — This process has primarily been developed for use in steel foundries. With this process stainless steel can be gouged at high speeds comparable to the speeds achieved in gouging mild steel using normal oxy-acetylene process.

8.13.9 *Powder Lancing* — The powder lancing technique provides a comparatively easy means of severing those materials which are hitherto proved impossible or uneconomical to cut by reason of heavy size or the oxides being of refractory nature.

The equipment consists of a special holder incorporating an injector and duel valve coupled to a high pressure oxygen supply and standard powder dispenser.

8.14 Multiple Cutting — For regular production of similar jobs an operator can simultaneoulsy operate a number of cutting blowpipes mounted on the same machine. As many as 20 cutting blowpipes have been used on the same machine to cut like number of identical shapes in one operation. This increases production and reduces cost of cutting.

8.15 Stack Cutting — Stack cutting is the cutting of multiple layers of material clamped together as though they were one thick piece of material. The advantages of stack cutting are increased productivity and economy in the consumption of gases. The resulting cut edges are square and more free of burrs and drag as compared to sheared edges. Optimum stack thickness is 75 to 100 mm.

It is very important that the clamping must be very effective so as to eliminate all air gaps especially along the line of cut. When sheets are involved, stack cutting may result in molten edges stuck together. In such cases a ' waste plate ' which is thrown away after the cut can profitably be used as the top of the stack. This prevents fusion of the cut edges of the sheets and neat cuts are possible. If the sheets are not clean and if clamping is not effective oxygen cutting becomes difficult and recourse has to be taken to powder cutting.

8.16 Accuracy of Oxygen Cutting — The degree of accuracy obtained depends on the thickness and intricacy of the job as well as the quality of equipment used. With efficient machines and by following proper procedures a tolerance of ±0·08 mm can be obtained (*see* IS : 6431-1971*).

8.17 Effect of Oxygen Purity — Oxygen of very high purity (99·5 percent or higher) should be used for cutting. It has been observed that one percent decrease of oxygen purity will result in increased consumption of cutting oxygen by about 25 percent. Apart from this, oxygen of lower purity reduces the speed of cutting and render cutting of higher thicknesses very difficult.

8.18 Distortion — Distortion in oxygen cutting can often pose serious problems. Distortion cannot perhaps be completely eliminated but can be reduced by adopting appropriate procedures of cutting. Rolling stresses locked up into the plate, transverse and longitudinal shrinkage, heat input, plates not level or supported at the time of cutting, are some of the factors that give rise to distortion. Some of the remedial measures used in practice are given below. These are only some of the basic rules intended to keep distortion to a minimum. An appreciation of the causes of distortion and experience add to the efficiency and accuracy of cutting:

a) Distortion due to locked up stresses are unpredictable; but generally these are not very significant. Transverse and longitudinal shrinkage can be estimated roughly and allowed for; a few trials will be necessary to ascertain these factors which will vary from work to work. Where very high accuracy is required and machining of the cut edge is called for, the job should be cut a little oversize.

b) The more the heat input the more will be the distortion. The fuel gas has therefore to be so chosen that the cutting speed is highest; acetylene would be a good choice.

c) Accurate levelling of plates is very important. If the plate surface is not horizontal and if a bevel is to be cut the angle of bevel will be entirely different from what is desired; if a template is used for cutting a circle the product will only be oval and the cut edge will not be square.

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*Tolerances on dimensions of plates cut by flame.

d) In order to prevent bowing it is necessary to support and hold the work rigidly to let the scrap move freely; the scrap should be cut off before it can move the work. Small wedges fitted into the kerf prevent the job or the scrap moving over and filling the gap made by cutting. Advantages of wedging can be noticed in cutting circles, where in the absence of wedges there will invariably be a small step at the start and finish of the cut

e) While cutting strips or long narrow profiles two cutters should be used; this spreads the input heat to both sides of the strip so that both sides react in the same fashion. Distortion is thus minimized due to even distribution of heat.

f) One of the most important rules is that the work should be left attached to the bulk of the material until the last possible moment.

SECTION 9

INSPECTION AND TESTING

9.0 General

Oxy-acetylene welding process can be used on the whole range of commercial ferrous and non-ferrous metals and alloys Materials, such as high carbon and alloy steels can be welded by oxy-acetylene welding provided the joints, if required, can be properly heat-treated before and after welding Cast iron machinery frames 30 cm or more thick at fracture point have been repaired by either fusion or braze welding (non-fusion welding) Sound welds are produced in other materials by appropriate variation in technique, heat-treatment, pre- and post-heating, etc. Generally speaking, oxy-acetylene welding is no longer used in structural work in mild steel, if arc-welding facilities are available, except in the case of relatively thin gauge material and pipes

With the progress in the use and acceptance of welding as a fabrication medium, inspection and testing of welds has assumed great importance To obtain a dependable joint it is necessary to inspect and exercise adequate control before, during and after welding It is also necessary to draw samples on a scientific basis and list them not only to control the quality of weld, but also to assess the skill and ability of the welder

Inspection and testing procedures for different welding processes vary considerably The various tests to be conducted on welded joints are determined mainly by the service conditions to which the welded components will be subjected Reference may be made to IS 822-1970* for details of inspection procedure

9.1 Inspection

Inspection for welding has to be carried out in three stages

a) Preliminary stage — Before commencing fabrication by welding

b) In-process stage — During fabrication by welding

c) Final stage — After welding

9.2 Inspection Before Welding

Inspection before the commencement of welding should cover all the aspects with a view to eliminating all potential sources of defects The aspects to be covered are

a) Drawings and specifications,

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*Code of procedure for inspection of welds

b) Selection of welding process,
c) Material specifications,
d) Inspection of materials,
e) Selection of consumables,
f) Inspection of consumables,
g) Welding procedure,
h) Welding equipment,
j) Welding operators,
k) Testing facilities, and
m) Ancillary equipment and facilities.

9.3 Inspection During Fabrication

Inspection during fabrication by welding is performed with the following objectives:

a) To ensure that the procedures, consumables, operators, etc, employed have been accorded prior approval;
b) To examine assemblies, weld preparations, etc, prior to start of welding to ensure that they are in conformity with approved procedures and are designed to give good welding;
c) To ensure by visual inspection during welding that a good finished weld results and defects, if any, in the initial stages are removed prior to further work;
d) To test welds which may become difficult to inspect at a later stage due to decreasing accessibility with the progress of work; and
e) To permit modifications, alterations, additions to procedures, consumables, operators previously accorded approval.

9.3.1 The inspection during this stage should cover aspects, such as:

a) inspection of prepared materials,
b) inspection of assemblies,
c) inspection of welding consumables,
d) operators,
e) welding procedures,
f) inspection during weldings, and
g) deviations.

9.4 Inspection After Welding

Inspection after welding is performed with a view to assessing:

a) the quality of weld by mechanical tests either on extension pieces or the actual fabricated component; and

b) the correctness of the whole weldment by visual and dimensional checks, by leak and load tests on the actual component.

9.4.1 Inspection during this stage should cover:

a) visual inspection;

b) inspection for weld dimensions;

c) mechanical tests;

d) non-destructive tests:

e) leak tests; and

f) load test, proof test and overload test.

9.4.2 The completed weld and the welded fabrication as a whole should be examined visually, preferably with the assistance of a magnifying lens to detect:

a) weld defects occurring at the surface, such as blow-holes, pipes, exposed porosity, exposed inclusions, unfilled cracks, unfused weld, etc;

b) surface cracks in the weld metal or in the parent metal adjacent to weld;

c) damages to the parent metal, such as undercut, burning, overheating, etc;

d) profile defects, such as excessive convexity or concavity, overlap, unequal leg lengths, excessive reinforcement, incompletely filled grooves, excessive penetration bead, roof grooves, shrinkage grooves, etc; and

e) incorrect finish, for example, ripple, weaving faults, chipping and peening marks, spatter, underflushing, overgrinding, uneven welds, etc.

9.4.3 Visual examination can also reveal:

a) distortion due to welding, that is, local shrinkage, camber, bowing, twisting, rotation, buckling waviness, etc;

b) linear, eccentric, angular and rotational misalignment of parts;

c) incorrect positioning of parts; and

d) visible dimensional errors.

9.5 Testing of Welds

In order to ensure the quality of welds, it is necessary to have an efficient system of testing. In general, mechanical tests are the least expensive and most reliable for assessing weld quality. Therefore, mechanical tests are most widely carried out.

Though there is general unanimity of opinion among welding engineers on the properties to be determined and the procedure of test, there is a wide divergence in the shape and size of test specimens and the details of test procedures The results obtained on test specimens prescribed in different codes and specifications, should not, therefore, be compared directly

9.6 Mechanical Tests

Mechanical tests are generally destructive tests except for tests like hardness testing In so far as the welds are concerned they can be performed on:

a) prototype or sample welds, and

b) extension pieces or test coupons

9.6.1 Mechanical tests may comprise of all or some of the following

a) *Tests for determining strength and ductility* — Tensile test, bend tests, impact test, load test, etc,

b) *Tests for determining continuity, fusion and soundness* — Bend test,

c) *Tests for determining penetration and internal weld configurations* — Macro-section etching; and

d) *Tests for determining metallurgical properties and local structural variations in weld and the heat affected zone* — Micro-structural examination, hardness survey, chemical analysis, etc

9.7 Non-destructive Testing

Weldments are also subjected to non-destructive testing Non-destructive testing covers the examination of welds which does not render the weldment unusable or cause damage to the weld Though visual and dimensional inspection are also non-destructive in nature, normally non-destructive testing covers the use of the following methods

a) Radiographic examination,

b) Ultrasonic testing,

c) Magnetic particle flaw detection,

d) Liquid penetrant flaw detection, and

e) Eddy current testing.

SECTION 10

ESTIMATING AND COSTING

10.1 General

Materials, labour and overheads constitute the cost of any fabrication work and it is true for oxy-acetylene welding also. Estimation of expenses for a job to be done by the oxy-acetylene process presents certain difficulties. The process is much more flexible than any of the welding processes — it is a very important point in its favour for its wide-scale adoption in industry and at the same time it often makes an estimation unrealistic as in practice the various factors that go into the costing may vary widely. The same work can be done at widely different speeds with widely different capacities of the welding blowpipe. In Tables 7.1, 7.2 and 7.3 are given welding speeds and data for leftward, rightward and vertical techniques of gas welding. The information given is based on good welding practice.

These tables are for guidance only and as observed earlier the different parameters can vary depending on the skill of the operator.

10.2 Cost of Fabrication by Gas Welding

In the following paragraphs the factors affecting the cost of a fabrication by oxy-acetylene welding have been evaluated:

a) *Base Material* — Base material shall be very carefully selected, keeping in view the wastage. Utilization of plates should be so planned that minimum scrap loss is involved; small components can be fabricated by using plates left over.

b) *Preparation for Welding* — While preparing the plate edges of welding judgment must be applied to ensure minimum scrap loss and an acceptable preparation (*see* Section 7). While for small thicknesses shear cutting is extensively used, oxygen cutting is generally recommended for thicknesses 3·15 mm and higher.

Use of wider bevel angles than necessary may lead to increase in cost. For example a 40° bevel in place of 30° bevel on a 6-mm thick plate will increase the cost of edge preparation by about 2 percent. The increase in cost of welding will be about 90 percent due to additional volume of filler metal and gases.

For each thickness, the specified size of nozzle, gas pressures and speed of cutting should be employed to obtain the best results. If the equipment is defective or the nozzle is unclean, uneven cuts will result. Although generally oxy-cut surfaces do not require any further finish prior to welding, extensive grinding will be necessary to rectify the defects which means extra expenses. Should the fit-up be poor due to uneven cutting the weld may be unsatisfactory and may even be rejected.

c) *Cost of Actual Welding Operation* — This includes cost of welding rods and fluxes, welding gases and labour charges.

10.3 Cost of Welding — The entire cost of welding can be broken down as follows:

a) Cost of edge preparation,

b) Cost of filler metal and flux (when required),

c) Cost of oxygen and acetylene gases,

d) Cost of post-weld finish or treatment,

e) Cost of labour, and

f) Overheads.

It is obvious that control must be exercised on all these factors for achievement of quality in the weldment and economy in fabrication.

10.3.1 *Cost of Edge Preparation* — The cost of edge preparation by oxy-cutting can be easily calculated by adding together the cost of gases consumed, labour charges and overheads. While consumption of oxygen can be easily calculated from the pressure-drop in the cylinder by simple multiplication and division on the basis of Boyles Law, the volume of dissoved acetylene is determined from the difference of weight of the cylinder before commencement and after completion of cutting on the basis that 1 m^3 of acetylene approximately weighs 1·1 kg.

10.3.2 *Cost of Filler Metal and Flux* — Approximate consumption of the selected wire can be estimated by the data given in Tables 7.1, 7.2 and 7.3.

Volume for volume the filler metal is generally 5 to 10 times more expensive than the base metal. It follows that a weldment to be economical must be designed with the least volume of weldment. Furthermore, saving in weld metal also means saving in labour, gases and associated overhead expenses. If the root gap between plates is increased from 1·5 to 2·5, the quantity of weld metal required will be about 60 percent more and the expenses for gases will also be approximately 50 percent more. Similarly, if the fit-up is not satisfactory the weld quality may deteriorate and the expenses may go up.

Over-welding is sometimes attempted to make the weld ' stronger '; this at once shows a lack of understanding of the principle on which the weldment is designed. If the design calls for a fillet weld with 6 mm leg length then a weld of that size is ample to carry the load safely. Admittedly, in manual welding, maintenance of an exact 6 mm leg may not be easy and in practice a tolerance ±1 mm is necessary. If the design does not permit even this degree of negative tolerance a little over-welding may become unavoidable.

For welding mild steel no flux is required. But flux which is a mixture of various chemicals is required for protection of the weld metal and base plate at the time of welding, say, aluminium, stainless steel or cast iron. On completion of a job, therefore, the cost of the flux used must also be taken into consideration. Different types of fluxes are required for welding different metals.

10.3.3 *Cost of Oxygen and Acetylene Gases* — For the purpose of estimation reference may be made to Tables 7 1, 7 2 and 7 3. These figures relate to welding of steel and hence for welding other materials, such as aluminium, stainless steel, etc, these figures will not apply. For calculation of actual quantities of oxygen and acetylene consumed in a particular job the following methods can be used:

10.3.3.1 *Oxygen* — The volume of oxygen consumed (v) can be calculated from the following formula:

$$v = \frac{V(P_1 - P_2)}{P}$$

where

V = volume of oxygen contained in the full cylinder,

P_1 = pressure of oxygen in the cylinder as indicated by the pressure regulator at the time of starting the work,

P_2 = pressure of oxygen in the cylinder as registered by the pressure regulator on completion of the job, and

P = original pressure at which the cylinder was filled by the suppliers.

The following example will further clarify the procedure:

> Suppose that a cylinder has been filled at a pressure of 125 kgf/cm^2 and the volume of oxygen in the cylinder at that pressure is 6 m^3. At the time of starting the work the pressure regulator registers a pressure of 100 kgf/cm^2 and on completion the pressure of oxygen in the cylinder is 50 kgf/cm^2. The volume of oxygen consumed for this work can be calculated as follows:
>
> $V = 6$ m^3
>
> $P = 125$ kgf/cm^2

$$P_1 = 100 \text{ kgf/cm}^2$$

$$P_2 = 50 \text{ kgf/cm}^2$$

$$v = \frac{6\ (100 - 50)}{125} \text{ m}^3$$

$$= 2{\cdot}4 \text{ m}^3$$

NOTE — The capacity of the cylinder and the pressure at which it has been filled should be ascertained from the suppliers.

10.3.3.2 *Acetylene* — Although a rough estimation is possible from Tables 7.1, 7.2 and 7.3, for exact calculation of acetylene consumed, the weight of the acetylene cylinder before commencing the job (W_1) and after its completion (W_2) will have to be taken:

$$v = \frac{W_1 - W_2}{1{\cdot}1} \text{ m}^3$$

10.3.4 *Cost of Post-Weld Finish or Treatment* — After-weld treatment, such as grinding, correction of distortion, etc, whenever applicable, have to be carried out. Proper sequence of welding may keep the distortion to a minimum and should be followed. Weld should be done so that minimum grinding, if at all, becomes necessary.

10.3.5 *Cost of Labour* — From the point of weld economics as well as weld quality it is essential to use the highest speed of welding. With the same flow rate of gases if a welder welds at a speed of 6 m/h and if another operator welds at a speed of 8 m/h it is obvious that the labour cost is increased by 25 percent if the first welder is employed for the job.

To minimize labour charges, it is also necessary to ensure that most of a welder's time is employed in actual welding; it may be more economical to employ a helper for unimportant work, such as tacking, positioning, etc, which otherwise the welder has to do himself. The main object is to increase this duty factor. This can be achieved by the following methods:

a) *Use of jigs, fixtures and manipulators* — It is well known that a welder can work better and faster in the downhand position because in this position, fatigue is less. It may de noted that if the cost of depositing a 6-mm fillet in the flat position is rated at 100 percent, the ratings for similar fillets in horizontal, vertical and overhead positions are approximately 150 percent, 300 percent and 400 percent, respectively.

b) Incentive schemes on the basis of quality of work and output.

10.3.5.1 The influence of the duty factor on labour cost is illustrated in the following table. A labour rate of Re 1·00 per hour and welding speed of 10 m/h at 100 percent duty cylce have been assumed:

Duty Factor	*Production*	*Labour Cost per Metre*
Percent	m/h	Paise
20	2	50
40	4	25
60	6	16
80	8	12
100	10	10

10.3.6 *Overheads*

Overheads vary from factory to factory and also depend upon the accounting system Generally for estimating purposes a factor of 200 percent of direct labour charge is assumed.

The total cost of fabrication can now be estimated by adding the costs of base material, filler, fluxes, where necessary, edge preparation, oxygen acetylene, labour and overheads.

APPENDIX A

(*Clause* 1.1)

DEFINITIONS OF COMMON WELDING TERMS

All-Position Rightward Welding — A variation of rightward welding in which the flame is approximately normal to the molten pool (*see* Fig. A-1).

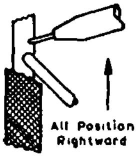


FIG. A-1 ALL-POSITION RIGHTWARD WELDING

Automatic Welding — Fusion welding in which control of the welding operation is predominantly automatic.

Backfire — The momentary recession of the flame into the blowpipe followed by immediate re-appearance or complete extinguishment of the flame, usually accompanied by an explosive sound.

Backing Ring — Backing in the form of a ring generally used in the welding of piping (*see* Fig. A-2).

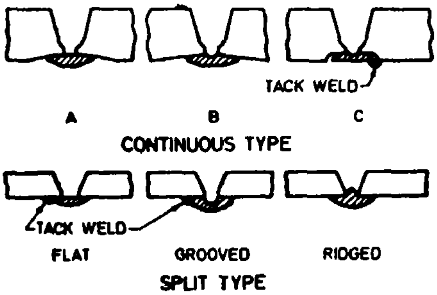


FIG. A-2 TYPICAL BACKING RINGS

Backing Strip — A piece of metal placed at a root and penetrated by weld metal. It may remain as part of the joint or may be removed by machining or other means (*see* Fig. A-3).

Blowhole — A large cavity due to entrapped gas.

NOTE — This term is conveniently applied to cavities exceeding 1·6 mm in diameter.

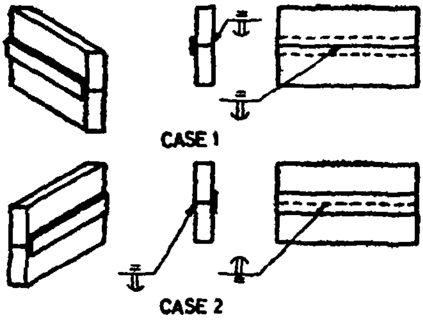


FIG. A-3 BACKING STRIP

Branch Tee Saddle Joint A joint between a branch pipe set at 90° to a main pipe, the end of the branch pipe being shaped to fit snugly against the main pipe (*see* Fig A-4).

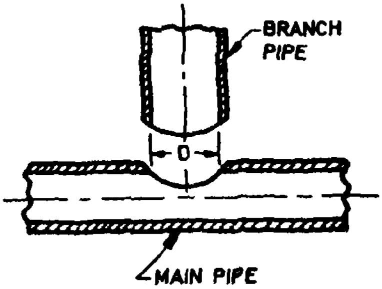


FIG. A-4 BRANCH TEE SADDLE JOINT

Brazing — A process of joining metals in which molten filler metal is drawn by capillary attraction into the space between closely adjacent surfaces of the parts to be joined. In general, the melting point of the filler metal is above 500°C

Dip Brazing — A process in which a workpiece is partially or totally immersed in a bath of molten filler metal which is covered by a layer of molten flux.

Flame Brazing (Torch Brazing) — A process in which heat for brazing is obtained from a gas flame from a manually operated blowpipe or torch.

Furnace Brazing — A process in which brazing heat is obtained by putting a complete workpiece into a furnace which may contain a protective atmosphere.

Induction Brazing — A process in which brazing heat is obtained by inducing high-frequency electric current within the material in the neighbourhood of the joint. A protective atmosphere may be used.

Resistance Brazing — A process in which brazing heat is obtained by:

a) the passage of an electric current between the parts to be joined, as in resistance welding; or

b) the passage of an electric current through two carbon electrodes and the parts to be joined The greater part of the brazing heat is generated in the electrodes and conducted to the joint.

Salt Bath Brazing — A process in which brazing heat is obtained by immersing a complete workpiece in a bath of molten salt of suitable melting point. The salt used should act as a flux.

Bronze Filler Metal – A filler metal used for bronze welding consisting basically of coper and zinc. It may also contain nickel, manganese, and/or other metals.

NOTE — The term ' bronze ' is not used here in the ordinary metallurgical sense.

Bronze Welding — A method of joining metals by means of the deposition of molten copper-rich filler metal on the parts to be joined, without necessarily fusing them. In general, the melting point of the filler metal is above 850°C.

NOTE — The meaning now attached to the term is quite arbitrary, since bronze is not used and the process is not necessarily welding Bronze welding, unlike brazing, does not depend upon capillary attraction.

Bell Butt Joint — A joint between two pipes of the same diameter, in which one pipe end is swaged out to receive the end of the other pipe (*see* Fig. A-5).

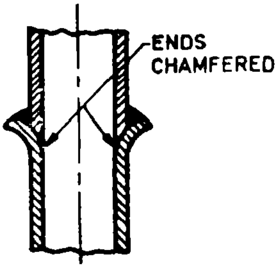


FIG. A-5 BELL BUTT JOINT

Butt Weld — A weld in which the weld metal lies substantially within the extension of the planes of the surfaces of the parts joined or within the extension of the planes of the smaller of the two parts of differing size (*see* Fig. A-6).

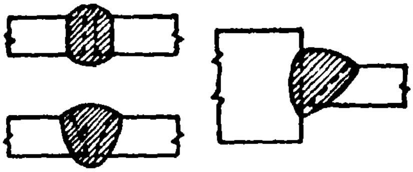


Fig. A-6 Examples of Butt Welds

Capillary Pipe — A fine pipe extending along the junction of weld and parent metal.

Note — The defect is caused by faults in the parent metal (for example, laminations or layers of segregation) mostly occurring along the whole length of the metal concerned.

Carburizing Flame — A reducing flame in which gas or gases burnt are carbonaceous.

Note — In an oxy-acetylene carburizing flame the inner cone is not sharply defined and is surrounded by a quantity of unburned gas known as a ' feather '.

Chipping Goggles — A protective device enclosing a space in front of the eyes to shield them from injury during chipping or grinding. They are fitted with two plain glasses.

Chipping Mark — An indentation resulting from chipping preparation or dressing. It gives rise to a dark shadow of corresponding shape in the radiograph.

Convexity — The maximum distance from the face of a convex fillet weld perpendicular to a line joining the toes.

Crack — A discontinuity produced either by tearing of the metal while in a plastic condition (hot crack or hot tear) or by fracture when cold (cold crack or cold tear).

Crater — A depression left in weld metal where the arc was broken or the flame was removed.

End Crater — A crater at the end of a weld or at the end of a joint.

Deposited Metal (Added Metal):

a) *In Welding* — Filler metal after it becomes part of the weld.

b) *In Bronze Welding or in Brazing* — Filler metal after it becomes part of the joint.

Diminishing Bell Butt Joint — A joint between two pipes of different diameters, in which the end of the smaller pipe is swaged out to fit the bore of the larger pipe (*see* Fig. A-7).

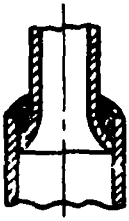


FIG. A-7 DIMINISHING BELL BUTT JOINT

Face Mask — A protective device worn in front of the face to shield it from injury during welding. It is fitted with welding glass(es) and plain glass(es).

Face Shield (Hand Screen, Hand Shield) — A protective device held in the hand to shield the face and throat from injury during welding. It is fitted with a window consisting of welding glass and plain glass.

Filler Metal — Metal to be added in welding or brazing.

Flame Snap-Out — Harmless unintentional extinction of a gas welding flame, sometimes accompanied by a minor explosion.

Flashback — Dangerous retrogression of a gas welding flame beyond the blowpipe body into the hose, with subsequent explosion.

NOTE — The violence of the explosion depends upon where it occurs.

Flash Welding (Flash-Butt Welding) — A resistance-welding process wherein coalescence is produced, simultaneously over the entire area of abutting surfaces, by the heat obtained from resistance to the flow of electric current between the two surfaces, and by the application of pressure after heating is substantially completed. Flashing and upsetting are accompanied by expulsion of metal from the joint.

Flux — Fusible material used in welding or oxygen-cutting to dissolve and facilitate removal of oxides and other undesirable substances. Also commonly used to designate covering of covered electrodes.

Full-Fusion Welding — A name given to gas (fusion) welding to distinguish it from surface-fusion (semi-fusion) welding and non-fusion welding.

Fusion Face — The portion of a surface, or of an edge, which is to be fused in making a fusion weld (*see* Fig. A-8).

Fusion Welding — Any welding process in which the weld is made between metals in a state of fusion without hammering or pressure.

Fusion Zone — The portion of a weld in which parent metal has been fused (*see* Fig. A-9).

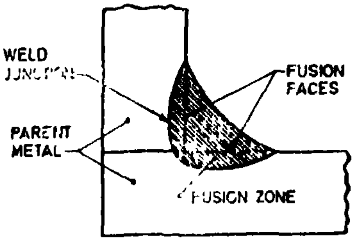


Fig. A-8 Fusion Face

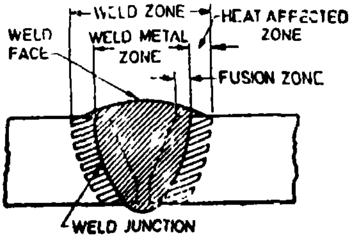


Fig. A-9 Various Zones of a Typical Weld

Gas Pore — A small cavity due to entrapped gas.

Note — This term is conveniently applied to cavities not exceeding 1·6 mm in diameter.

Gas Welding — A group of welding processes wherein weld is produced by heating with a gas flame or flames, with or without the application of pressure and with or without the use of filler metal.

Helmet (Head Screen) — A protective device supported on the head and arranged to shield the face and throat from injury during welding. It is fitted with a window consisting of welding glass and plain glass.

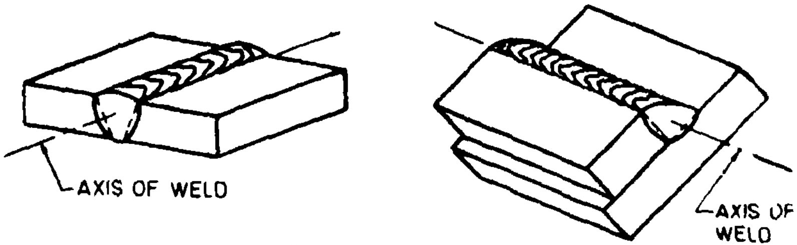
Heat-Affected Zone — Parent metal metallurgically affected by the heat of welding (or cutting), but neither melted nor made plastic (*see* Fig. A-9).

Inclusion — Slag or other foreign matter entrapped during welding.

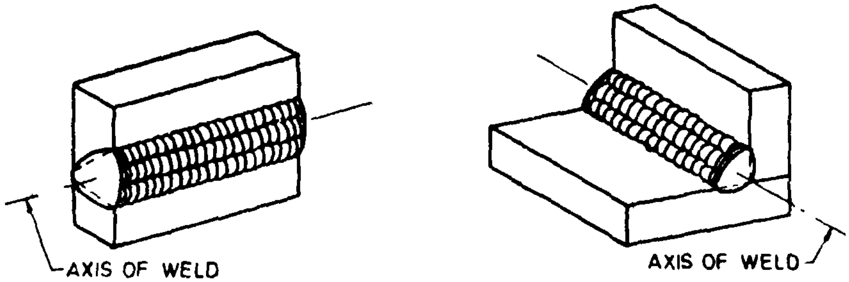
Longitudinal Axis of Weld — A line through the length of a weld, perpendicular to the cross section at its centre of gravity (*see* Fig. A-10).

Non-fusion Welding — A term applied to the deposition, by the oxy-acetylene process, of filler metal on parent metal without fusion of the latter.

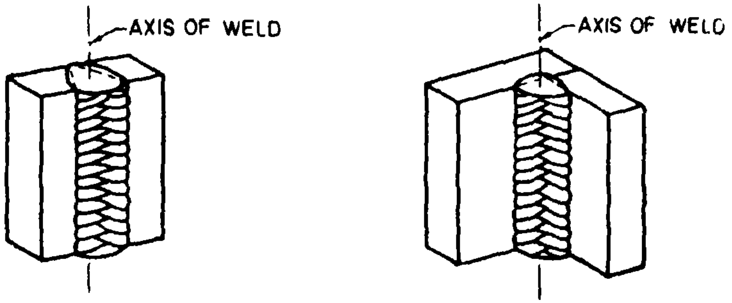
Overlap — An imperfection at a toe or root of a weld caused by metal flowing on to the surface of the parent metal without fusing to the latter (*see* Fig. A-11).



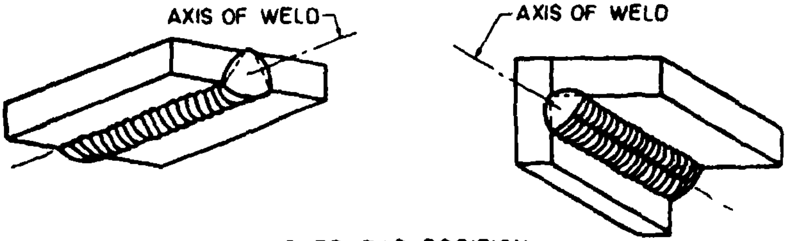
FLAT POSITION



HORIZONTAL-VERTICAL POSITION



VERTICAL POSITION



OVERHEAD POSITION

Fig. A-10 Longitudinal Axis of Welds

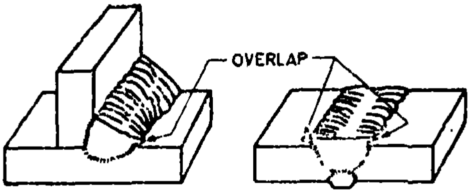


FIG. A-11 OVERLAP

Peening — The mechanical working of metals by means of hammer blows.

Pick-Up — That property of a flux which causes some of it to adhere to the heated end of a filler rod, that is, the property which gives rise to the ' tuft ' which is applied to the molten pool.

Plain Glass (Cover Glass) — Clear glass or other transparent material used to protect the surface of welding glass.

Porosity — A group of gas pores.

NOTE — Porosity may be conveniently differentiated according to size as fine, medium, or coarse, and may occur as clusters or chains, or may be scattered.

Pressure-Welding (Solid-Phase Welding) — Any welding process in which the weld is made by sustained pressure while the surfaces to be united are plastic.

Projection Welding · Resistance welding in which throughout the making of a weld the pressure is applied at a small projection or projections on one or more of the workpieces. The projections collapse during welding.

Resistance-Butt Welding — A resistance-welding process wherein weld is produced, simultaneoulsy over the entire area of abutting surfaces or progressively along a joint, by the heat obtained from resistance to the flow of electric current through the area of contact of those surfaces. Pressure is applied before heating is started and is maintained throughout the heating period.

Resistance Welding (Upset Welding) — Welding in which pressure is applied between abutting surfaces at some stage in the process, and in which welding heat is produced by the electrical resistance at, and adjacent to, these surfaces during the passage of an electric current.

Roller-Spot Welding — Resistance welding in which pressure is applied continuously, and current impulsively, to produce a series of intermittent linear welds, the workpiece being between two electrode wheels or between an electrode wheel and an electrode bar. The electrode wheels apply the pressure, and may be rotated continuously or stopped during the passage of current.

Root Concavity — An intermittent broad groove, or series of cavities, occurring in submerged-arc welding in the penetration bead, or in the root, of a weld.

NOTE — The imperfection occurs when a copper backing-bar is used, and is caused by fused flux powder trickling through the irregular abutting faces of the parent metal and the copper backing-bar.

Seam Welding — Resistance welding in which pressure is applied continuously, and current impulsively, to produce a linear weld, the workpiece being between two electrode wheels, or between an electrode wheel and an electrode bar. The electrode wheels apply the pressure, and may be rotated continuously or stopped during the passage of current.

Semi-automatic Welding — Arc welding with equipment which controls only the filler metal feed. The advance of the welding is usually manually controlled.

Series-Spot Welding -- Spot welding in which two or more welds are made simultaneoulsy in electrical series (*see* Fig. A-12).

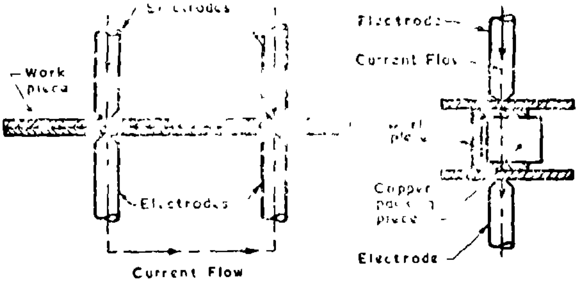


FIG. A-12 EXAMPLES OF SERIES-SPOT WELDING

Short Bell Branch Joint — A branch joint in which the metal round a hole in a main pipe is swaged out to receive the end of a branch pipe (*see* Fig. A-13).

Spot Welding — A resistance-welding process wherein weld is produced by the heat obtained from resistance to the flow of electric current through the work parts held together under pressure by electrodes. The size and shape of the individually formed welds are limited primarily by the size and contour of the electrodes.

Surface-Fusion Welding (Semi-fusion Welding) — Gas welding in which a carburizing flame is used to melt the surface of the parent metal, which then unites with molten metal from a suitable filler rod.

NOTE — This application is used for Linde welding, hard-surfacing building-up and the like.

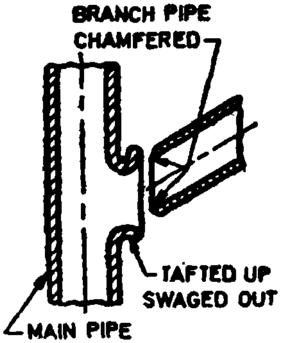


FIG. A-13 SHORT BELL BRANCH JOINT

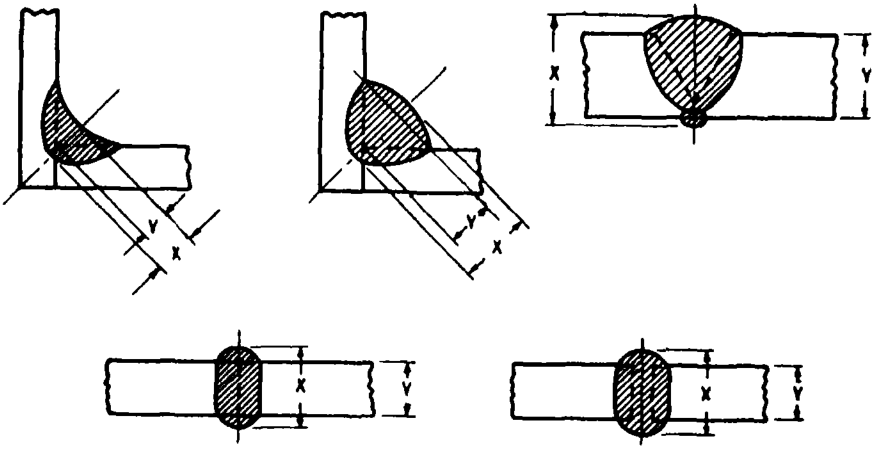
Surfacing — The deposition of filler metal by welding process on to a metal surface to obtain desired properties.

Sustained Backfire — Possibly harmful retrogression of a gas welding flame into the blowpipe neck or body, the flame remaining alight.

NOTE — It is usually accompanied by popping or squealing and sometimes there is small pointed flame at the nozzle.

Throat Thickness — The minimum thickness of weld metal in a fusion weld measured as under (*see* Fig. A-14):

a) *For a Fillet Weld or a V-, U-, J- or a Bevel-Butt Weld* — Along a line passing through the root.



X = THROAT THICKNESS
Y = EFFECTIVE THROAT THICKNESS AS USUALLY ADOPTED

FIG. A-14 EXAMPLES OF THROAT THICKNESS

b) *For a Close Square-Butt Weld* — In the plane of the abutting faces.

c) *For an Open Square-Butt Weld* — At the centre of the original gap in a plane parallel to the fusion faces.

Toe of Weld (Weld Edge) — The junction between the face of a weld and the parent metal.

Undercut — A groove cut into the base metal along the toe of a weld and left unfilled by the weld metal.

Underflushing — A reduction in metal thickness due to excessive dressing.

Weaving — Transverse oscillation of the arc end of an electrode or of a blowpipe nozzle during the deposition of weld metal (*see* Fig. A-15).

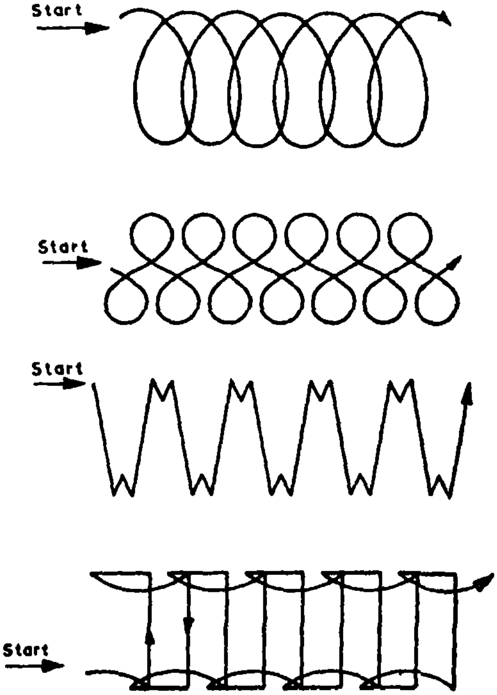


FIG. A-15 WEAVE MOTIONS

Weld — A union between two pieces of metal at faces rendered plastic or liquid by heat or by pressure, or both. Filler metal may be used to effect the union.

Weld Cycle — The time required for one complete welding operation.

Weld Face — A surface of a fusion weld exposed on the side from which the weld has been made (*see* Fig. A-16).

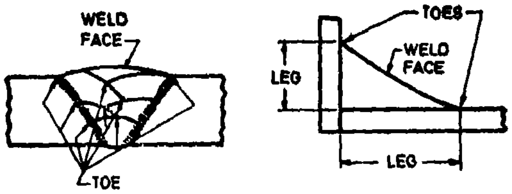


FIG. A-16 EXAMPLES OF WELD FACES, TOES AND LEGS

Weld Width — Distance between the toes of the weld.

Weld Zone — The sum of the weld-metal zone and the heat-affected zone (*see* Fig. A-9).

Weldable Fitting — A specially shaped component of suitable copper alloy, fitted to copper or copper-alloy pipe to facilitate joining them by bronze welding.

Welding Current — The current flowing through the welding circuit during the making of a weld. In resistance welding, the current used during pre-weld or post-weld intervals is excluded.

Welding Glass (Filter Glass) — A light-filter to protect the eyes from harmful radiations emanating from an electric arc or a gas flame.

Welding Gloves — Gloves to protect the hands, or gauntlets to protect the hands and forearms, from heat and metal splashes due to welding.

Welding Goggles — Goggles with tinted lenses used during welding or oxygen cutting to shield eyes from injury during welding or cutting.

Welding Procedure — A specified course of action to be followed in welding, including a list of materials and tools to be used. Three typical examples of welding procedure are given below:

a) *Arc Welding*
   1) Classification and size of electrodes;
   2) Current and open-circuit voltage;
   3) Length of run per electrode, or speed of travel;
   4) Number and arrangement of runs in multi-run welds;
   5) Position of welding;
   6) Preparation and set-up of parts;
   7) Welding sequence; and
   8) Pre- or post-heating.

b) *Gas Welding*

1) Specification and diameter of filler rod and, if required, specification of the flux;
2) Gas pressures and nozzle size;
3) Manipulation and angles of rod and blowpipe and, if required, correct application of flux;
4) Technique of welding;
5) Edge preparation and, if required, tacking;
6) Position of welding and number of runs;
7) Welding sequence; and
8) Pre- or post-heating.

c) *Resistance Welding*

1) Electrodes sizes and permissible variations,
2) Particulars of machine settings,
3) Welding sequence, and
4) Particulars of tests required.

APPENDIX B

(*See* Foreword)

INDIAN STANDARDS ON WELDING

Sl No. *Number and Title of the Standard*

1. IS : 812-1957 Glossary of terms relating to welding and cutting of metals
2. IS : 813-1961 Scheme of symbols for welding (*amended*)
3. IS : 814(Part I)-1974 Covered electrodes for metal arc welding of structural steels: Part I For welding products other than sheets (*fourth revision*)
4. IS : 814(Part II)-1974 Covered electrodes for metal arc welding of structural steels: Part II For welding sheets (*fourth revision*)
5. IS : 815-1974 Classification and coding of covered electrodes for metal arc welding of structural steels (*second revision*)
6. IS : 816-1969 Code of practice for use of metal arc welding for general construction in mild steel (*first revision*)
7. IS : 817-1966 Code of practice for training and testing of metal arc welders (*revised*)
8. IS : 818-1968 Code of practice for safety and health requirements in electric and gas welding and cutting operations (*first revision*)
9. IS : 819-1957 Code of practice for resistance spot welding for light assemblies in mild steel
10. IS : 822-1970 Code of practice for inspection of welds
11. IS : 823-1964 Code of procedure for manual metal arc welding of mild steel
12. IS : 1024-1968 Code of practice for welding of structures subject to dynamic loading
13. IS : 1179-1967 Equipment for eye and face protection during welding (*first revision*)
14. IS : 1261-1959 Code of practice for seam welding in mild steel
15. IS : 1278-1972 Filler rods for gas welding (*second revision*)
16. IS : 1323-1966 Code of practice for oxy-acetylene welding for structural work in mild steel (*revised*)

Sl No.	*Number and Title of the Standard*
17.	IS : 1393-1961 Code of practice for training and testing of oxy-acetylene welders
18.	IS : 1395-1971 Molybdenum and chromium-molybdenum low alloy electrodes for metal arc welding (*second revision*)
19.	IS : 2751-1966 Code of practice for welding of mild steel bars used for reinforced concrete construction
20.	IS : 2811-1964 Recommendations for manual tungsten inert-gas arc welding of stainless steel
21.	IS : 2812-1964 Recommendations for manual tungsten inert-gas arc welding of aluminium and aluminium alloys
22.	IS : 2927-1975 Brazing alloys (*first revision*)
23.	IS : 3016-1965 Code of practice for fire precautions in welding and cutting operations
24.	IS : 3023-1965 Recommended practice for building-up by metal spraying
25.	IS : 3525-1966 Code of practice for use of metal arc welding for hull construction of merchant ships in mild steel
26.	IS : 3600 (Part I)-1973 Code of procedure for testing of fusion welded joints and weld metal in steel: Part I General tests (*first revision*)
27.	IS : 3613-1974 Acceptance tests for wire flux combinations for submerged arc welding of structural steels (*first revision*)
28.	IS : 4353-1967 Recommendations for sub-merged arc welding of mild steel and low alloy steels
29.	IS : 4943-1968 Assessment of butt and fillet fusion welds in steel sheet plate and pipe
30.	IS : 4944-1968 Code of procedure for welding at low ambient temperatures
31.	IS : 4972-1968 Resistance spot welding electrodes
32.	IS : 5139-1969 Recommended procedure for repair of grey iron castings by oxy-acetylene and manual metal arc welding
33.	IS : 5206-1969 Corrosion-resisting chromium and chromium nickel steel covered electrodes for manual metal arc welding

Sl. No.	*Number and Title of the Standard*
34.	IS : 5462-1969 Colour code for identification of covered electrodes for metal arc welding
35.	IS : 5511-1969 Covered electrodes for manual metal arc welding of cast iron
36.	IS : 5530-1969 Code of procedure for repair and rectification of steel castings by metal arc welding processes
37.	IS : 5687-1970 Glossary of terms relating to welding of plastics
38.	IS : 5856-1970 Corrosion and heat resisting chromium nickel steel solid welding rods and bare electrodes
39.	IS : 5857-1970 Nickel and nickel alloy bare solid welding rods and bare electrodes
40.	IS : 5897-1970 Aluminium alloy welding rods and wires and magnesium alloy welding rods
41.	IS : 5898-1970 Copper and copper alloy bare solid welding rods and electrodes
42.	IS : 5922-1970 Qualifying test for welders engaged in aircraft welding
43.	IS : 6016-1970 Hose connection for welding and cutting appliances
44.	IS : 6227-1971 Code of practice for use of metal arc welding in tubular structures
45.	IS : 6409-1971 Code of practice for oxy-acetylene flame cleaning
46.	IS : 6419-1971 Welding rods and bare electrodes for gas shielded arc welding of structural steel
47.	IS : 6431-1971 Tolerances on dimensions of plates cut by flame
48.	IS : 6580-1972 Molybdenum and chromium-molybdenum low alloy steel welding rods and bare electrodes for gas shielded arc welding
49.	IS : 6901-1973 Pressure regulators for gas cylinders used in welding, cutting and related processes
50.	IS : 6916-1973 Code of practice for fabrication welding of steel castings
51.	SP : 6(7)-1972 ISI Handbook for structural engineers: Simple welded girders
52.	ISI Handbook of manual metal arc welding for welders

Sl No.	*Number and Title of the Standard*
53.	IS : 7273-1974 Methods of testing fusion welded joints in aluminium and aluminium alloys
54.	IS : 7280-1974 Bare wire electrodes for submerged arc welding of structural steels
55.	IS : 7303-1974 Covered electrodes for surfacing of metal by manual metal arc welding
56.	IS : 7307 (Part I)-1974 Approval tests for welding procedures: Part I Fusion welding of steel
57.	IS : 7310(Part I)-1974 Approval tests for welders working to approved welding procedures: Part I Fusion welding of steel
58.	IS : 7318(Part I)-1974 Approval tests for welders when welding procedure approval is not required: Part I Fusion welding of steel
59.	IS : 7318 (Part II)-1974 Approval tests for welders when welding procedure approval is not required: Part II TIG or MIG welding of aluminium and its alloys
60.	IS : 7653-1975 Manual blowpipes for welding and cutting

APPENDIX C

(*See* Foreword)

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